Rb-Sr Study of Rapakivi Granite and Augen Gneiss of the Risberget Nappe, Oppdal, Norway

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Rb-Sr dating of rapakivi granite and associated augen gneiss of the Risberget Nappe suggests that the rocks are post-Svecokarelian intrusions that were strongly foliated during the Caledonian orogeny. Microstructures of the augen indicate igneous crystallization followed by cataclastic and ductile deformation, and the augen are interpreted as porphyroclasts rather than metasomatic porphyroblasts. Rb-Sr data from 56 presumably co-magmatic rapakivi rocks yield an errorchron date of 1618 ± 44 Ma with low initial Sr ratio (.7021 ± 5). The least deformed rapakivi samples are isotopically disturbed and partially reset, while an isochron from an ultramylonite within the Risberget Nappe yields a date within the range of error of the suggested 1618 Ma intrusive date. The dating of a younger pegmatite intrusion (1163 ± 80 Ma) suggests that the rocks were subjected to a Sveconorwegian event. Minerals of unfoliated rapakivi granite are only partially reset to Sveconorwegian and Caledonian dates, while minerals of foliated rocks yield Caledonian isochrons.

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Introduction

The distinctive coarse augen gneisses of the Western Gneiss Region are especially well known from the Oppdal district. Törnebohm (1896) correlated them with the Precambrian granite and augen gneiss of the Caledonian allochthon of Jämtland. Bjørlykke (1905) and Goldschmidt (1916) considered them to be derived from Caledonian granitic intrusions. Carstens (1924, 1925) showed that some of the Oppdal augen gneisses have wiborgitic rapakivi textures, i.e., with thin plagioclase rims mantling the large K-feldspar megacrysts, and that they compare reasonably well in composition, texture and mineralogy with the type rapakivi rocks in Finland. He further demonstrated the isochemical transition of massive rapakivi rock to foliated augen gneiss. Barth (1938) and Holtedahl (1938) developed theories of granitization by suggesting a metasomatic origin for the augen. Rosenqvist (1943) documented the presumed metasomatic changes with descriptions and chemical analyses of the various rock types.

The origin of the augen gneiss by large-scale metasomatism has generally been accepted. This interpretation has strongly influenced previous mapping and stratigraphic/structural interpretation, as augen gneisses were only mapped where 'well developed'. More recently, Eggen (1977) mapped and interpreted them as deformed igenous rocks, and Solheim (1980) interpreted Rb-Sr dating to show that any metasomatism must have been Precambrian. Krill (1980a, 1980b) supported these recent studies and the earlier interpretations of Törnebohm and Carstens, suggesting that the Oppdal augen gneisses are not metasomatic but Precambrian porphyritic granites that were cataclastically deformed during the Caledonian orogeny. They form a major part of the Caledonian Risberget Nappe.

Textures of the granite and augen gneiss

The earlier studies included detailed petrographic and geochemical descriptions, and only the most significant textural features are mentioned here. Large pods of massive or weakly foliated rapakivi granite are preserved within the augen gneiss. In the rapakivi granite (Fig. 1), K-feldspar phenocrysts are mainly single-crystal and Carlsbad-twinned ovoids, ranging up to 15 cm in diameter. Most of the phenocrysts are mantled by a continuous rim of plagioclase, generally 2–5 mm thick and independent of the size of the K-feldspar core. The K-feldspar (Fig. 2) is mainly pink to purple perthitic microcline with inclusions of plagioclase, quartz, biotite and hornblende. The inclusions are randomly oriented, rarely in concentric zonal patterns, and have optical properties and grain sizes similar to those of minerals in the matrix.

Fig. 1. Massive rapakivi granite with shear zone. (UTM coord. 322206). Ruler is 16 cm long.

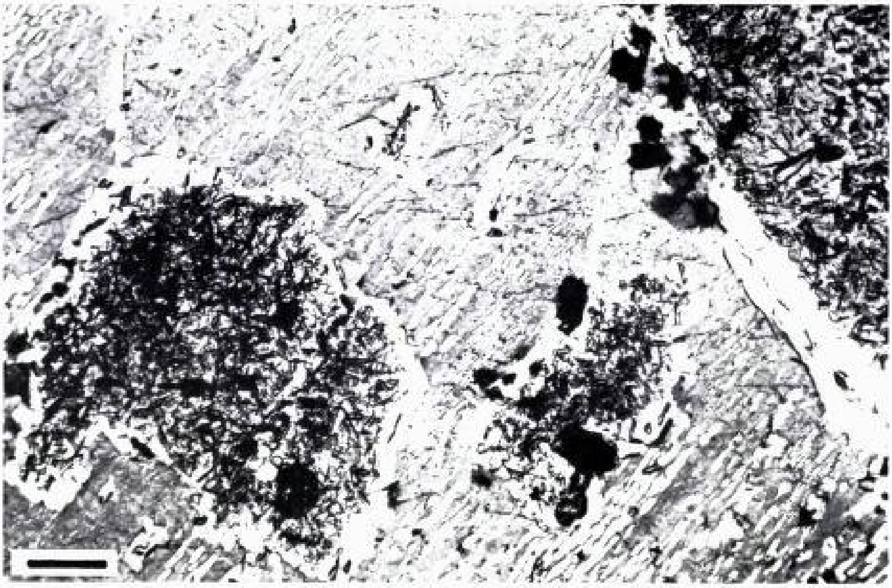

Fig. 2. Rapakivi K feldspar megacryst and matrix. The megacryst is perthitic, and the plagioclase rim (upper right corner) and included grains are saussuritized (note zoisite). Inclusion-free plagioclase separates saussuritized plagioclase from K-feldspar. Bar scale = 0.1 mm. Crossed polars.

The plagioclase rim consists of large albite-twinned grains, nearly optically continuous with each other and with the K-feldspar core. The plagioclase is strongly saussuritized with abundant zoisite inclusions. All the plagioclase in each rock – in the mantle, as augen inclusions, and in the matrix – has the same appearance and composition (An 10–30).

The very dark matrix of the underformed rock is produced by Fe-rich biotite and ferro-paragasitic hornblende, both typical of rapakivi granites (Simonsen & Vorma 1969). Other matrix mineral are idioblastic garnet, blue quartz, saussuritized plagioclase, ilmenite with rims of sphene, zircon and very minor uralitized clinopyroxene. No fine-grained K-feldspar is found in the matrix, suggesting that K-feldspar did not nucleate easily, allowing the few crystals that did nucleate to grow quite large.

Strain textures are apparent even in the least deformed rapakivi granite. K-feldspar megacrysts are commonly fractured, the slightly offset segments separated by margins of granular quartz. Quartz and feldspar are strained with strongly undulose extinction. Matrix biotite may define a weak foliation, but a simple statistical measure of the shape and position of phenocrysts using a method by Ramsay (1967, p. 195) demonstrates the random, massive texture of the granite.

Rapakivi mantled feldspars can develop from various igneous crystallization paths (Tuttle & Brown 1958, Steward & Roseboom 1962), and their exclusively igneous origin is now generally recognized. Many exolved minerals also indicate that the rock first formed at high igneous(?) temperature and partially re-equilibrated at a lower metamorphic temperature. Perthitic K-feldspar demonstrates albite solid solution, and deep colors of K-feldspar indicate a high Fe-content. Zoisite inclusions in plagioclase (Fig. 2) indicate original anorthite solid solution, and blue quartz presumably is due to rutile. Altered relict clinopyroxene also suggests an original temperature higher than that of the regional metamorphism.

Most parts of the rapakivi granite were later deformed into rapakivi augen gneiss with a variety of textures. Some phenocrysts are reduced to thin augen lenses, where the pink K-feldspar cores and greenish plagioclase mantles produce dramatic ribbons (Fig. 3). Cataclastic processes dominate the feldspar deformation, and in thin-section the ribbons are mosaics of equigranular K-feldspar and plagioclase (Fig. 4). Single feldspar crystals with deformed shapes were never found in thin-sections of elongate, flat or folded augen lenses.

Even where no mantled feldspar are found (Fig. 5), textural features of the augen gneiss indicate that augen are relict porphyro*clasts* and not newly formed porphyro*blasts*. The large K-feldspar augen commonly contain inclusions of plagioclase, quartz, biotite and hornblende. The inclusions are always randomly oriented, not foliated as they would be if included during porphyroblastic growth of metasomatic augen in a foliated gneiss. Inclusions are coarse grained as in the undeformed granite, whereas the minerals in the foliated matrix are cataclastically reduced and recrystallised to finer grained foliated textures: The plagioclase inclusions retain albite twins (Fig. 6) and zoisite inclusions, while matrix plagioclase is recrystallized and free of twins or zoisite.

Fig. 3. Strongly foliated rapakivi augen gneiss (304240). Plagioclase mantles are visible despite granulation and deformation of the augen. Scale in cm.

Fig. 4. Augen gneiss of Fig. 3. Note the zoisite needles in lens of fine-grained plagioclase (P). No zoisite in lens of fine grained K-feldspar (K). Bar scale = 0.1 mm. Plane-polarised light.

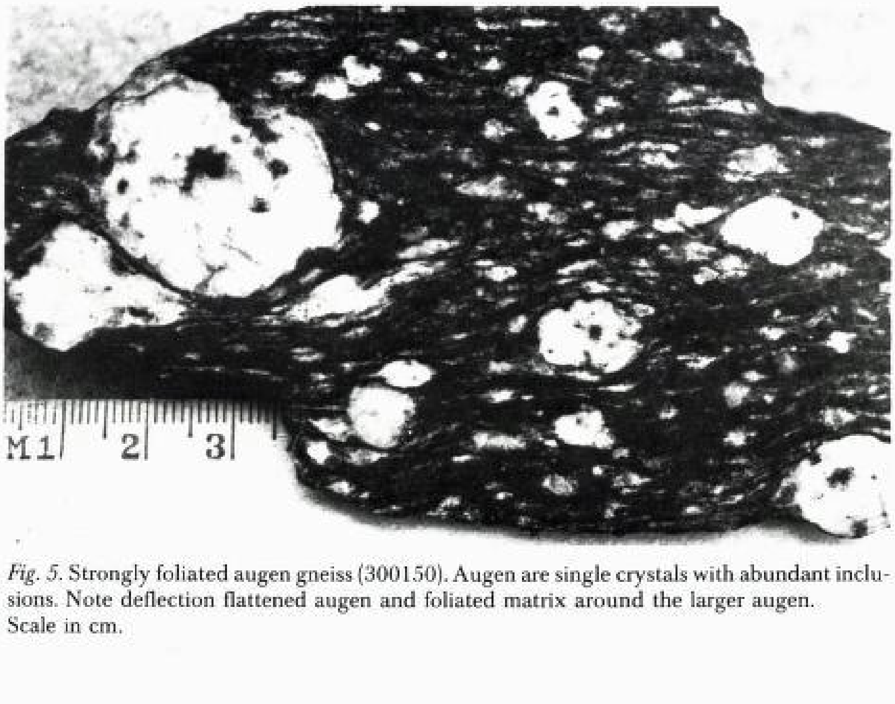

Fig. 5. Strongly foliated augen gneiss (300150). Augen are single crystals with abundant inclusions. Note deflection flattened augen and foliated matrix around the larger augen. Scale in cm.

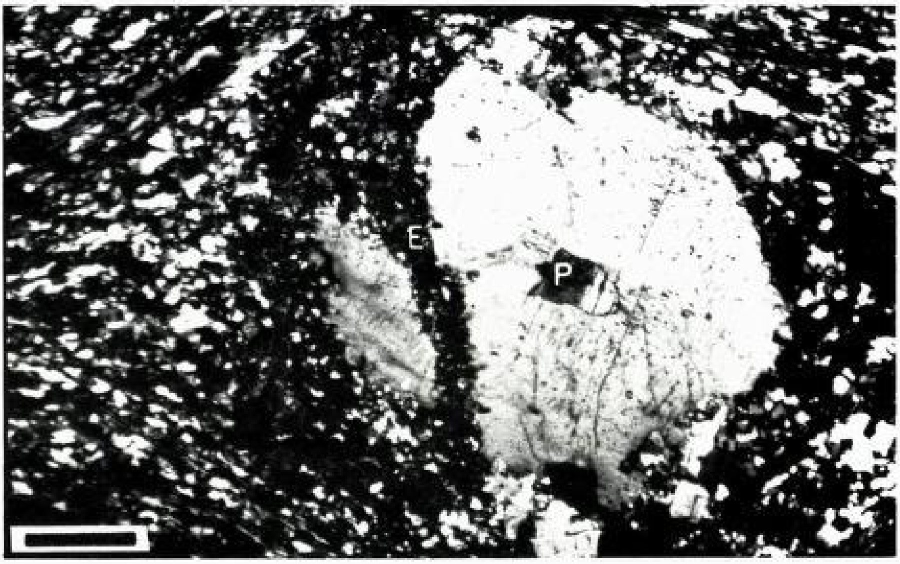

Fig. 6. Small K-feldspar porphyroclast in augen gneiss. Note deflection of matrix around augen. Plagioclase inclusion (P) contains secondary zoisite and shows albite twins. Granular epidote (E) separates K feldspar segments. Bar scale = 1 mm. Crossed polars.

Streaks of flattened augen and matrix minerals bend around the larger, more competent augen. If these augen were porphyroblasts, they would have had to have pushed the matrix minerals aside. Even such dense minerals as garnet apparently do not have such a 'force of crystallization' (Spry 1969) and it seems unlikely that a growing K-feldspar augen could push aside streaks of K-feldspar and denser matrix minerals. Rather the deflection of the matrix is a typical cataclastic texture, as illustrated by Higgins (1971). The rocks could be classified as mylonite or mylonite gneiss, in which the augen are porphyroclasts of normal appearance but unusually large size.

Textures diagnostic of feldspar porphyroblastesis, such as foliation that has been truncated by augen, or overgrown and preserved as helecitic traces in augen, have not been recognized in the Oppdal augen gneisses. The augen cannot be sedimentary clasts, as they are very evenly and widely distributed. No quartz augen (cobbles) are found, and the average quartz content of the augen gneiss (c. 20%) is too low for it to be a normal clastic metasedimentary rock. The feldspar:quartz ratio of the augen is too high for the augen to be an anatectic melt phase, but the normative K-feldspar:plagioclase:quartz ratio of the entire rock is that of eutectic granite (Eggen 1977).

No wiborgitic plagioclase mantles are recognized in much of the Oppdal augen gneiss. The original mantles may have been destroyed by deformation, but it is perhaps more likely that the original igneous rock itself lacked mantles. Such porphyritic rock without wiborgitic mantles is common in rapakivi massifs in Finland, where it is termed pyterlite.

Small pods of light-colored granitic gneiss locally float in the darker augen gneiss. Granulation at the edges of the pods has produced medium-grained grnaitic augen, which are quite different from the large-crystal K-feldspar augen of the typical augen gneiss. Such granite-clast augen gneiss composes only a small part of the Risberget augen gneisses, although inclusion-filled single-crystal augen (Fig. 5) can look like granite clasts.

Granular fine-grained gneiss containing K-feldspar, plagioclase, quartz, epidote, biotite, muscovite and garnet is commonly associated with the Oppdal augen gneiss. It is typically well foliated or flaggy, but a consistently low quartz content (<30%) suggests that it is orthogneiss and not feldspathic psammite. It commonly contains many small, millimeter-sized, feldspar augen and a few large single-crystal augen per outcrop. As in the typical augen gneiss, textural and mineralogical features of the augen indicate that they are porphyroclasts. However, the field appearance of a few large augen in a fine-grained flaggy gneiss might deceptively suggest a metasomatic origin.

Anorthosite and anorthosite-gabbro are closely associated with the Oppdal rapakivi granite, and these rocks fit an interesting global pattern. Post-tectonic of anorogenic rapakivi granite and anorthosite of Mid-Proterozoic age are scattered in an arc across the northern hemisphere from the Ural Mountains to western North America. (Bridgrewater & Windley 1973).

Rb–Sr dating

The first Rb-Sr study of Oppdal augen gneiss and other rocks of the Risberget Nappe was undertaken by Solheim (1980). He presented whole-rock results from seven suites of Risberget rock, including granite, gneiss, augen gneiss and metagabbro. The data points are somewhat scattered on the Rb-Sr plots, and produced errorchrons rather than true isochrons. Some points were arbitrarily deleted to reduce the scatter, and the age results are difficult to interpret in these cases. As presented, the errorchron dates range from 1129 ± 302 Ma to 1737 ± 106 Ma. The initial Sr ratios have large uncertainties and do not faciliate interpretation of the errorchrons. Mineral separates from a single sample of strongly foliated gneiss yielded an isochron date of 392 ± 21 Ma. The whole-rock errorchrons were interpreted as the result of a resetting event following the main metamorphism. The mineral isochron date was interpreted as the age of low-grade heating, or uplift and cooling.

My Rb-Sr study focused on the rapakivi granite and gneisses derived from it. Rocks of three suites were analyzed: massive rapakivi granite, strongly foliated mylonite gneiss, and intensely deformed ultramylonite. Detailed descriptions of the rocks, locations, and analytical methods are presented elsewhere (Krill 1980a) and briefly summarized in the appendix. Analytical data are listed in Tabel 1. The 56 whole-rock analyses define an errorchron corresponding to a date of 1618 ± 44 Ma ($^{87}Sr/^{86}Sr_O$ = .70211 ± 48, MSWD = 43, Fig. 7a. The large MSWD value quantifies the large amount of scatter. If the rocks are all co-magmatic, the scatter must have resulted from geological disturbance or contamination. The initial Sr ratio is low, within the predicted range of mantle-derived intrusive rocks. An isochron with such low initial Sr ratio is usually interpreted as the original igneous age of the rocks (Jäger 1979). However, the present example is an errorchron (Brooks et al. 1972), and must be interpreted with caution. I tentatively suggest that the date of 1618 Ma reflects the age of the rapakivi magmatism. This interpretation is supported by dating of similar rapakivi rock at Flatraket, 150 km to the west, where a zircon date of 1520 ± 10 Ma was interpreted as the intrusive age (Lappin et al. 1979). It also compares well with the dating of porphyritic rocks from the Tännäs Nappe in Jämtland, where a Rb-Sr date of 1610 ± 85 Ma and a zircon date of 1685 ± 20 Ma were interpreted to reflect the intrusion age (Claesson 1980).

RAPAKIVI GRANITE

The samples of unfoliated rapakivi granite which form part of the 1618 Ma errorchron were collected south of Oppdal from a relatively wide part of the Risberget Nappe. Glacially smooted hillside exposures prevent routine sampling, so samples were obtained from large boulders in a rockslide. The distinctive texture and the small sample area suggests that all samples were locally derived and co-magmatic.

Twelve samples averaging about 4 kg each from nine separate boulders yield a highly scattered errorchron: 1237 ± 228 Ma, $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}_{\mathrm{O}} = .7068$, MSWD = 16. Eleven smaller samples (c. 0.5 kg) from a single rapakivi boulder give similar isotopic scatter and regression results: 1376 ± 584 Ma, $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}_{\mathrm{O}} = .7060 \pm 52$, MSWD = 19. There seems to be no significant isotopic difference between these small, closely spaced samples and the larger, widely spaced ones. In Fig. 7b both are plotted together, yielding another errorchron: 1182 ± 115 Ma, $^{87}\mathrm{Sr}/^{86}\mathrm{Sr}_{\mathrm{O}} = .70756 \pm 128$ MSWD = 23, N = 23.

The 1182 Ma date is considerably younger than the presumed igneous age, and the initial Sr ratio is much higher. Scatter of the points off the best-fit line is large, and these dates cannot be considered meaningful. The isotopic systems have apparently been disturbed or contaminated on the whole-rock scale.

RAPAKIVI MINERALS

Minerals from one of the samples were also analysed. They are also disturbed and do not form an isochron, but mineral-whole rock pairs define the following dates and initial Sr ratios (Fig. 7c):

W.R.-Ksp:	1734 ± 144 Ma,	.69877 ± 206
Ksp-plag:	1134 ± 33 Ma,	.70920 ± 22
W.R.-plag:	740 ± 36 Ma,	.71074 ± 22
W.R.-biot:	368 ± 10 Ma,	.71518 ± 28

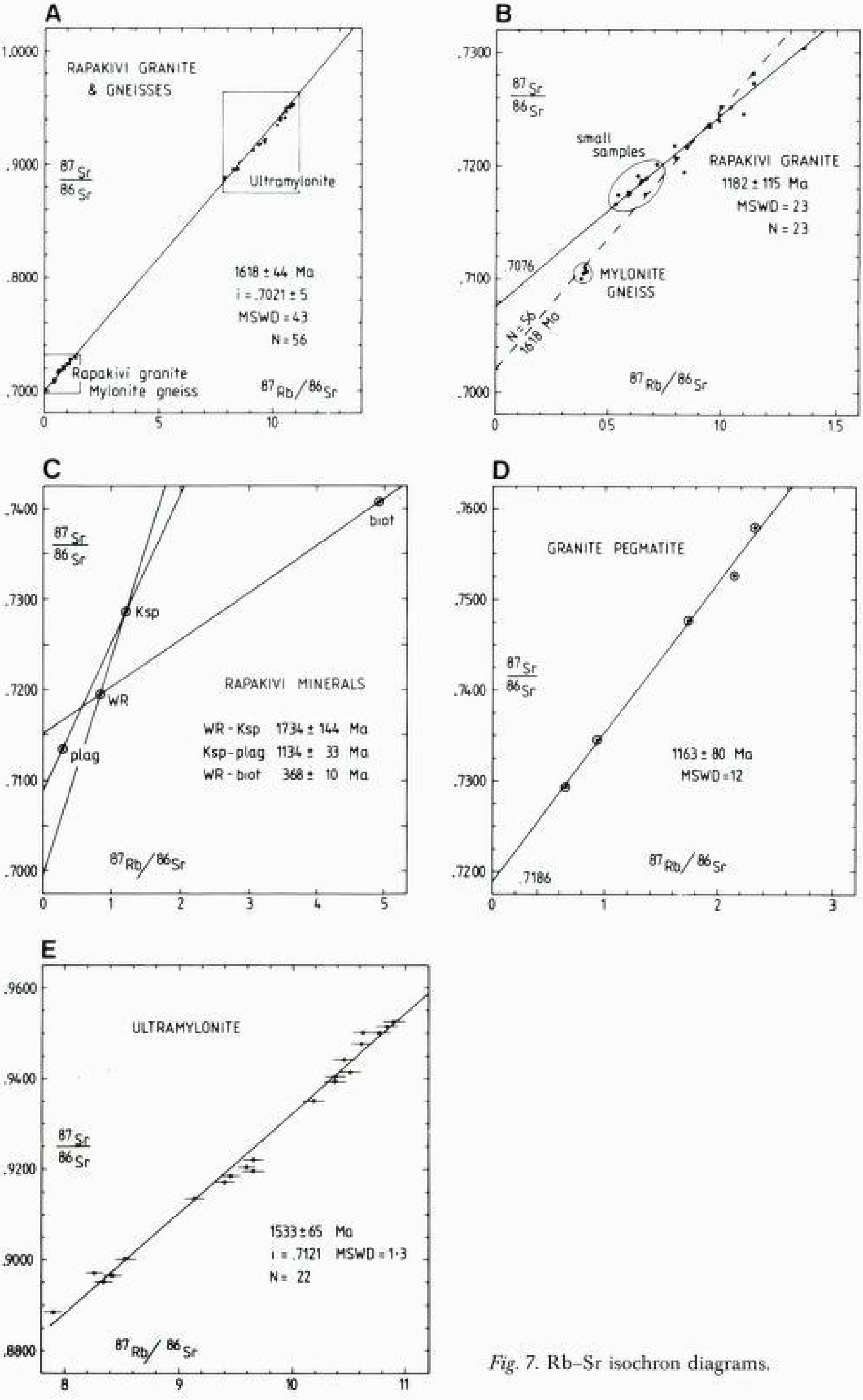

Fig. 7. Rb–Sr isochron diagrams.

Without performing similar analyses on other samples to confirm these dates, only tentative interpretations are possible. The 1734 ± 144 date apparently reflects the date of the rapakivi-granite intrusion. The initial Sr ratio is clearly too low, and therefore the date is probably too old, but both are presumably within the range of calculated errors. The 1134 Ma date may well be meaningless – a partial resetting to a younger age. However, it may record a thermal event, which re-equilibrated the Sr isotopes of the plagioclase mantles and the K-feldspar cores. The 740 Ma date is probably meaningless, since the plagioclase isotopes would more readily reequilibrate with the adjacent K-feldspar than with the whole-rock isotopic value. The 368 ± 10 Ma date probably represents the time of final cooling of the rocks. Although the rock produces no isochron, such disturbed mineral dates must be expected, as thin-sections clearly show secondary metamorphic mineral effects without complete recrystallization.

GRANITIC PEGMATITE

A granite pegmatite within coarse-grained augen gneiss yielded a 5-point whole-rock errorchron of 1163 ± 80 Ma (^{87}/Sr/^{86}Sr$_{o}$ = .71864 ± 134, MSWD = 12, Fig. 7d). The pegmatite is weakly foliated together with the augen gneiss and is sheared along its contacts. The initial Sr ratio is relatively high, as is typical for pegmatites derived from crustal rocks. The 1163 Ma date may be the intrusive age of the pegmatite, and would support an interpretation that similar dates from the rapakivi granite and K-feldspar–plagioclase pair are meaningful. It is not clear from the field relationships whether the pegmatite actually cuts any earlier foliation in the augen gneiss. The pegmatite is apparently not comagmatic with the repakivi rocks, as it shows no rapakivi texture or characteristic rapakivi minerals. The five samples are not included in the 56-point regression of the 1618 Ma errorchron.

MYLONITE GNEISS

Eleven of the analyses for the 1618 Ma date are from strongly foliated rapakivi mylonite gneiss within about 10 meters of the contact to the Sætra Nappe. No date was possible because of the lack of Rb/Sr spread, but ^{87}Sr/^{86}Sr analyses were carried out on all eleven samples to determine the amount of scatter. Scatter of the data is indeed very small; all eleven rocks have very similar ratios. Any secondary processes that may have influenced the isotopic ratios must have been very uniform. The tight cluster of points suggests that any very late non-penetrative disturbance was insignificant.

Because of the medium-grained texture and regular foliation of the mylonite gneiss, cross-cutting fractures, retrogression zones and weathered surfaces are easily identified and avoided in sampling. This rock may be inherently safer to use in geochronologic studies than the very coarse-grained rapakivi granite, in which secondary effects are extremely difficult to identify.

ULTRAMYLONITE

Ultramylonite from a several meter thick zone within the Risberget Nappe provides the remaining analyses for the 1618 Ma errorchron. The rock has a fine-grained granular texture caused by tectonic granulation and recrystallization of the minerals (cf. Higgins 1972, Sibson 1977). The parent rock was apparently a K-rich variety of rapakivi granite, almost completely lacking mafic minerals. Some tiny K-feldspar augen remain, and within the same outcrop some plagioclase-mantled K-feldspar porphyroclasts are preserved in coarser augen gneiss of similar potassium-rich composition. The ultramylonite has a strong foliation and lineation parallel to Caledonian fabrics in the Sætra Nappe, exposed as a tectonic slice about 30 m to the south, and I tentatively interpret it to be a Caledonian ultramylonite, not a relic of Precambrian deformation.

Samples were taken from a single ultramylonite block about 0.5 m^3 in volume. No significant isotopic differences were noted between samples of varying size and relative position within the block. Analyses fall on the same line and are regressed together, yielding an isochron: 1533 ± 65 Ma, $(^{87}Sr/^{87}Sr)_o = .7121 \pm 1.3$, N = 21 (Fig. 7e). Sample 122 was deleted from the regression. It falls below the other points and would completely change the regression line, creating an impossibly low initial Sr ratio. This sample has a distinctive biotite layer which apparently is not in isotopic equilibrium with the other rocks of this suite.

It is interesting that the ultramylonite is the most intensely deformed and recrystallized of the Risberget rocks studied, and yet it yields a true isochron that is within the error of the suggested 1618 Ma age of the igneous source rock. The least deformed rapakivi-granite boulders, on the other hand, yield scattered errorchrons with younger trends.

Discussion of the Rb–Sr dating

This study and the Rb–Sr study of Solheim (1980) provide useful information for interpretation of the Oppdal gneisses. The rocks clearly have a Precambrian origin. None of the whole-rock errorchron dates are as young as the Caledonian event and only a few are within the range of a possible Sveconorwegian event. The very low initial Sr ratio (.7021) of the rapakivi errorchron suggests that the rocks are of igneous origin, and not derived from older acidic crust. Derivation of the augen gneiss by regional metasomatism or granitization is very unlikely. Any K-rich metasomatic fluids would be expected to have relatively long crustal histories with high $^{87}Sr/^{86}Sr$ ratios. If such fluids could produce an errorchron from widely-spaced rocks of variable composition, the resulting initial Sr ratio would predictably be much higher.

The cause of the scatter of the Rb-Sr data is unknown. Rapakivi granites are known for being especially vulnerable to weathering (Eskola 1930), which could easily disturb the Rb and Sr. Even undeformed post-tectonic rapakivi rocks commonly produce anomalously young, scattered mineral dates (Bridgewater & Windley 1973). Data of the ultramylonite and of the massive rapakivi granites each produce lines with shallower slopes and higher initial Sr ratios than the presumed original isochron. This pattern may indicate partial equilibration of Sr isotopes with respect to some average isotopic composition (e.g. Field & Råheim 1979). Complementary U–Pb study of zircons could perhaps demonstrate whether these younger dates are meaningful or only an incomplete resetting to some younger date.

The Precambrian errorchrons do not contradict the interpretation that the rocks were strongly deformed and metamorphosed at amphibolite-facies conditions during the Caledonian orogeny (Krill 1983). Orthogneisses commonly retain older whole-rock dates despite younger tectonic events (Krill & Griffin 1981), and although the Risberget rocks were not reset, Oppdal schists and gneisses that are considered Caledonian (Krill 1980) have yielded Caledonian errorchron dates and Caledonian model ages (Råheim 1977, Solheim 1977, Krill unpubl. data). The fact that foliated rocks give fully reset Caledonian mineral isochrons (Solheim 1980) whereas minerals from massive rocks are only partially reset (Fig. 7c), supports the geological conclusion that the foliation is Caledonian.

Summary

The new Rb-Sr date presented here supplement the initial Rb-Sr study of Solheim (1980) and allow several tentative interpretations to be made. The 56-point errorchron date of 1618 ± 44 Ma is considered to represent the age of rapakivi-granite intrusion. Similar augen gneisses without obvious rapakivi textures may have also intruded at about this time, or they may be younger. Solheim (1980) obtained several errorchron dates of about 1450 Ma with very large uncertainties, and these dates may also represent intrusive ages. The c. 1150 Ma dates from the pegmatite, rapakivi granite and K-feldspar–plagioclase minerals may reflect a Sveconorwegian thermal event with pegmatite intrusion. The c. 395 Ma mineral isochrons from foliated basement and Risberget augen gneiss (Solheim 1980) presumably date the strong foliation, and the 358 Ma date of unoriented biotite in the rapakivi granite (this study) apparently reflects the cooling age.

It is notable that not a single Caledonian whole-rock date has been obtained from the Risberget Nappe, despite the very large number of analyses and the clear geologic and geochronologic evidence that the rocks are Caledonized gneisses. It appears that for the definitive interpretation of these and other problematic Rb-Sr dates from the Western Gneiss Region, additional geochronological data using other decay systems (U-Pb or Sm-Nd) will be necessary.

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Appendix

ANALYTICAL TECHNIQUES

The samples were crushed in a steel-jaw crusher and finely ground in a steel-ring mill. Rb/Sr ratios were determined directly by x-ray fluorescence (Pankhurst & O'Nions 1973). Mass spectrometry was performed on a Micromass MS30 at the Mineralogisk-Geologisk Museum, Oslo. Variable mass discrimination in $^{87}Sr/^{86}Sr$ was corrected by normalizing $^{88}Sr/^{86}Sr$ to 8.3752. The ^{87}Rb decay constant used was 1.42×10^{-11} yr.$^{-1}$, and the data were regressed by the method of York (1969). In assigning errors, the coefficient of variation was taken as 1 % for $^{87}Rb/^{86}Sr$. The errors for the $^{87}Sr/^{86}Sr$ measurements are listed in Table 1. Age and intercept errors are quoted at the 2-sigma confidence level.

Table 1. RB–SR DATA

Sample No.	Wt. (kg)	Rb (ppm)	Sr (ppm)	87Rb/86Sr	87Sr/86Sr	1-sigma
Rapakivi granite (boulders)						
25	3.9	123	316	1.14	.72818	13
26	6.6	124	314	1.14	.72732	8
27	2.0	116	304	1.10	.72463	5
28	5.8	109	320	.991	.72404	10
29	2.8	108	314	.995	.72455	5
30	4.1	110	309	1.04	.72535	8
31	1.7	98	210	1.36	.73045	16
32	5.0	104	358	.847	.72170	8
33	5.9	98	359	.792	.72181	11
34	1.8	102	314	.941	.72352	9
35	1.9	98	357	.800	.72075	7
266	3.6	88	307	.834	.71955	10
Small sample (single boulder)						
105	0.5	80	396	.589	.71770	8
106	0.7	80	396	.589	.71745	7
107	0.5	77	377	.591	.71746	6
108	1.0	88	410	.627	.71905	8
109	0.5	83	374	.645	.71878	9
110	0.3	88	383	.670	.71897	5
111	0.2	75	409	.534	.71665	9
112	0.2	84	384	.636	.71843	7
113	0.4	100	407	.713	.72021	8
114	0.3	77	414	.543	.71743	10
115	0.5	85	371	.667	.71752	8
Mylonite gneiss						
14	4.3	56	400	.405	.71073	5
15	1.2	56	401	.406	.71074	5
16	1.3	56	411	.400	.71095	5
17	2.8	54	401	.391	.71148	9
18	1.2	55	399	.403	.71079	4
19	1.5	52	393	.387	.71062	7
20	0.7	55	394	.403	.71060	6
21	1.5	54	409	.387	.71087	4
22	2.0	54	408	.384	.71011	6
23	2.2	55	398	.400	.71104	10
24	1.6	54	403	.393	.71064	6

Sample No.	Wt. (kg)	Rb (ppm)	Sr (ppm)	87Rb/86Sr	87Sr/86Sr	1-sigma
Ultramylonite						
1	0.5	273	85	9.40	.91731	10
2	0.5	270	84	9.45	.91810	4
3	0.5	278	85	9.65	.91968	8
4	0.5	279	84	9.65	.92224	14
5	0.4	282	87	9.59	.92061	8
6	1.6	264	93	8.34	.89523	16
7	0.8	252	90	8.26	.89736	7
8	3.1	267	93	8.42	.89670	8
9	1.0	265	85	9.14	.91386	9
10	1.7	283	80	10.38	.94063	14
11	1.4	265	91	8.53	.90048	7
12	3.1	284	82	10.19	.93512	4
116	0.4	291	79	10.84	.95192	8
117	0.3	292	79	10.89	.95272	5
118	0.2	281	77	10.77	.95007	10
119	0.3	284	79	10.61	.94789	12
120	0.6	288	80	10.63	.95036	9
121	0.5	265	99	7.90	.88858	8
122	0.6	239	146	4.79	.80402	5
123	0.6	285	80	10.51	.94150	9
124	0.5	280	79	10.46	.94437	5
125	0.5	285	81	10.38	.93950	10
Granitic pregmatite						
184	0.9	115	145	2.32	.75801	3
185	1.0	32	142	.658	.72939	6
186	0.8	127	173	2.14	.75268	5
187	1.0	96	161	1.73	.74775	10
188	1.2	53	166	.931	.73468	8
Minerals sample no. 266						
Ksp		184	444	1.20	.72869	8
plg		50	535	.271	.71361	5
bio		164	97	4.92	.74099	9

SAMPLE LOCATION, DESCRIPTIONS

Rapakivi granite

The sample locality is a boulder rockslide about 1 km south of Drivstua (UTM coord. 32502080). All samples are weakly foliated to unfoliated, but are rusty weathered on outside surfaces and internal fractures. See text and Carstens (1924) for petrographic descriptions.

Mylonite gneiss

About 0.5 m^3 in volume, from a newly blasted quarry road-cut south of the southermost Engan flagstone quarry (UTM coord. 29952425). All samples are from a single loosened slab. The rock is very dark, with strong gneissosity defined by lenses of granulated, rotated and recrystallized feldspar from original augen. The lenses are a few mm thick and several cm in length and width. Biotite forms a weak mineral lineation. The rock is c. 20% Ksp, 25% plag, 20% qtz, 15% biot, 10% musc and 10% epid, with accessory sphene and opaque. No chlorite is seen.

Ultramylonite

Samples were collected about 2 km north of Drivstua from a newly blasted road-cut on highway E-6 (UTM coord. 20582400). The samples are from a single block 0.5 m^3 in volume in a fine-grained layer. The rock is tan-colored and fractures conchoically. It appears homogenous and is not layered, but has very strong foliation (N15E, 35SE) and lineation (S75E, 35). Rare biotite layers a few cm wide are parallel to the foliation. Scattered K-feldspar augen are up to a few mm in diameter. The rock is c. 45% Ksp, 20% Ksp, 20% plag, 25% qtz, with accessory epid, gar, biot and musc.

Granitic pegmatite

The dike is exposed along highway 16, 9 km southwest of Lønset (UTM coord. 090385). It contains K-feldspar, plagioclase, quartz, biotite and muscovite. It averages about 1 meter in width, and is foliated together with the augen gneiss.