Resetting of a Rb-Sr total rock system in Rödingsfjället Nappe Complex, Nordland, North Norway

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A Rb-Sr total rock isotope study of an orthogneiss in Simafjell within the Rödingsfjället Nappe Complex (RNC) in Nordland has revealed a system of several sub-isochrons indicating a resetting event at about 380 m.y. (late Caledonian time). The result also supports a Precambrian origin for the rocks in question. It is suggested that other Rb-Sr regression lines may be interpreted in a similar way, and that sampling procedures strongly affect the outcome of such studies.

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The object of this note is to draw attention to the composite Rb-Sr isochron presently reported, and its potential significance. Conditional on the sampling procedure applied, similar isochrons are likely to be common in multiple-deformed rocks such as the central Caledonian fold belt. Their interpretation will have a bearing upon the current debate as to the relative importance of Precambrian and Caledonian events in the evolution of the Uppermost Allochthon.

The study area which is situated in the Simafjell area c. 8 km north of the Bleikvassli base-metal sulphide mine in the Rödingsfjället Nappe Complex (RNC) (Kulling 1955), forms, together with the Helgeland Nappe Complex (HNC) (Ramberg 1967, Gustavson 1975), the Uppermost Allochthon of the north central Caledonides. To the east, the HNC/RNC are underlain by the low-grade Köli nappes. For general reference the readers are referred to review papers by Gustavson 1978, Ramberg et al. 1981, Stephens et al. 1983.

Investigations of lithological and structural relationships have shown that this part of the RNC may be divided into two super-groups, perhaps representing internal basement and cover sequences (Brattli 1983). The possible basement complex is mainly composed of a variety of

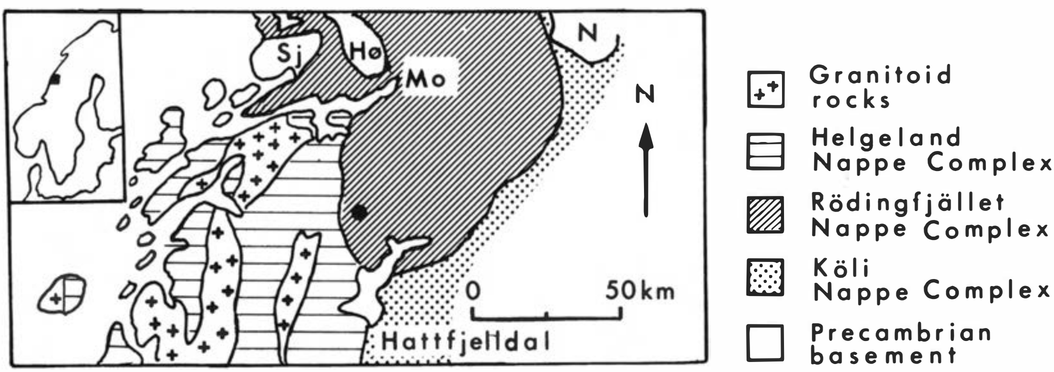

Fig. 1. Principal tectonostratigraphic units of part of the northern Scandinavian Caledonides (simplified from Gustavson 1978). Black dot indicates location of study area in Simafjell. Sj = Sjona, Hø = Høgtuva, N = Nasafjell window, Mo = Mo i Rana

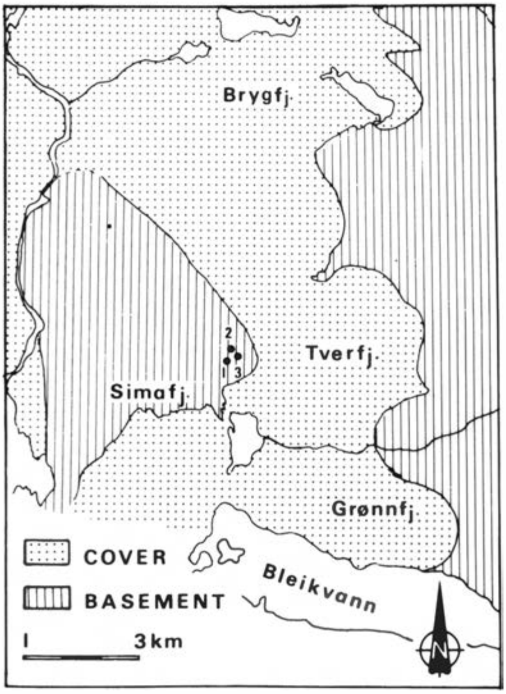

Fig. 2. Basement-cover map of Grønnfjell-Simafjell-Tverfjell-Brygfjell area, Helgeland, North Norway (Brattli 1983). Black dots show sample localities within the orthogneiss which constitutes a small part of the basement complex.

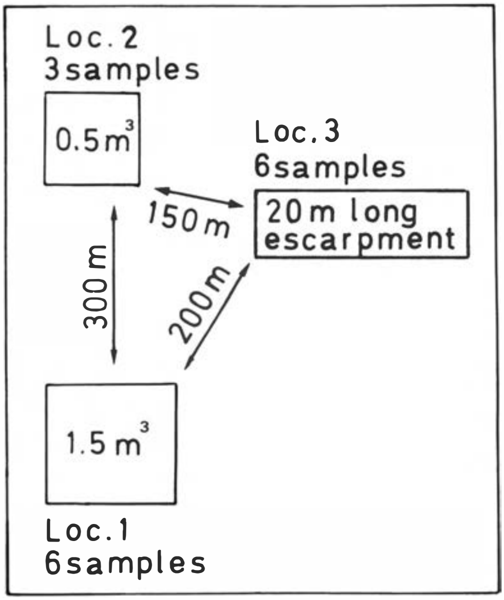

Fig. 3. Sketch of the sample localities.

gneisses (biotite-amphibole gneiss, quartz-feldspar gneiss, muscovite gneiss, granitic gneiss), whereas the possible cover sequence is largely made up of marbles, mica schists and amphibolites. The area in question has been affected by four clearly distinguishable phases of folding, although earlier deformation events seem to have contributed to the overall structural evolution (and style) of the basement gneisses.

The first two phases (F_1, F_2) led to tight to isoclinal folds, whereas the last two (F_3, F_4) led to open folds. The main deformation and regional schistosity are correlated with F_1, whereas structures such as roddings, mullions, extensional feldspar-augen and the predominant mineral lineation all belong to F_2. The regional metamorphism took place during F_1 and is of medium to high grade (Winkler 1976).

Chloritization of garnet and biotite, and growth of randomly oriented white mica are common textural features related to F_3 and F_4.

The present Rb-Sr whole rock isochron study is from a granitic gneiss within the presumed basement complex of the RNC. Two different ways of interpreting total rock Rb-Sr systems (from the Caledonides) have been applied. If Rb-Sr isochrons, or reasonable regression lines occur, they date a metamorphism or a superimposed metamorphism (e.g. Råheim 1977, Solheim 1980) or they date the primary origin of the rocks even if they suffered a high metamorphism and associated extensive deformation at a later time (e.g. Krill & Griffin 1981, Claesson 1980). We will present a Rb-Sr total rock study designed to test the main interpretation possibilities given above, in an area where the geology is well known.

Occurrence and nature of the gneiss

The investigated gneiss is situated in an antiformal (F_3/F_4 interference) structure in the basement complex (Fig. 2). The gneiss, which constitutes a small part of the basement complex, covers about 2 km^2. It has an irregular outline, and is affected by the same structural events as the surrounding rocks. It has a granitic composition and a fine to medium grained matrix. The K-feldspar forms augen 1–2 cm in cross section, strongly elongated parallel to the F_2 direction. The overall evidence suggests that it represents a pre- to syn-tectonic orthogneiss.

Table 1. Analytical data from the orthogneiss, Simafjell.

Serie	Sample	Rb[a]	Sr[a]	$^{87}Rb/^{86}Sr$[b]	$^{87}Sr/^{86}Sr$[c]
1	A	149.9	181.9	2.39	0.73240 ± 0.00012
	B	143.1	174.1	2.38	0.73195 ± 0.00010
	C	128.4	234.8	1.58	0.72782 ± 0.00018
	D	131.2	229.1	1.66	0.72840 ± 0.00012
	E_1	138.1	171.4	2.34	0.73220 ± 0.00010
	E_2	140.7	158.1	2.58	0.73334 ± 0.00012
2	F	127.1	120.2	3.07	0.73881 ± 0.00014
	G	137.1	139.1	2.86	0.73826 ± 0.00008
	H	130.2	129.4	2.92	0.73858 ± 0.00008
3	I	205.2	117.4	5.08	0.76052 ± 0.00010
	J	175.8	129.3	3.95	0.75467 ± 0.00022
	K	189.9	99.5	5.55	0.76235 ± 0.00010
	L	181.6	125.0	4.22	0.75544 ± 0.00012
	M	175.8	121.9	4.19	0.75562 ± 0.00012
	N	186.8	122.6	4.43	0.75756 ± 0.00010

a) By x-ray fluorescence, ppm.
b) Precision ± 1%
c) Precisions for $^{87}Sr/^{86}Sr$ is quoted as 2 σ standard error of mean

Sampling and analytical techniques

Samples were collected from three localities (Figs. 2,3). The distances between the localities vary from 150 to 300 m. The sampling took place in the most homogenous parts of the gneiss. Fresh samples of approximately 3–5 kg were collected using explosives. One series was collected at each locality.

Locality 1. Six samples were collected from a block of approximately 1.5 m^3.
Locality 2. Three samples were collected from a block of approximately 0.5 m^3.
Locality 3. Six samples were collected along a 20 m slope.

The rocks were crushed in a steel jaw crusher. The Rb-Sr ratio was determined by X-ray fluorescence and mass spectrometry was performed on a Micromass MS 30 (Pankhurst & O'Nions 1973). The ^{87}Rb decay constant used is 1.42 × 10 $^{11}yr^{-1}$. The age and intercept error is quoted at the 2 σ confidence level.

Results

The Rb-Sr data are given in Table 1, and the total rock isochron diagram is shown in Fig 4. Each series of samples falls within distinct groups in the isochron diagram. Two of the series yield regression lines (York 1969). The abbreviations used below are: IR = Initial $^{87}Sr/^{86}Sr$ and MSWD = Mean Square of Weighted Deviates (Brooks et al. 1972).

Locality 1. 383 ± 19 m.y. IR = .71926± .00580 MSWD = 2.14
Locality 2. No age calculation is possible.
Locality 3. 362 ± 50 m.t. IR = .73416 ± .00320 MSWD = 3.36

Interpretation of Rb-Sr results

A Rb-Sr study on late tectonic granitic dykes intruding the RNC in Sweden shows that they yield an isochron age of 447 ±7 m.y. (Claesson 1979). These dykes cut the main schistosity and the age is considered a lower limit for the timing of the regional metamorphism and the major structural events in the area. This conclusion is supported by ages of 433 ± 10 m.y. and 419 ± 9 m.y. on late tectonic dykes in the HNC (Tørudbakken, Skauli & Ramberg, in prep.). We interpret these data as showing that the major structural events (F_1 and F_2) and main metamorphism in the uppermost allochthons (RNC/HNC) are older than these ages.

The ages obtained on the Simafjell orthogneiss

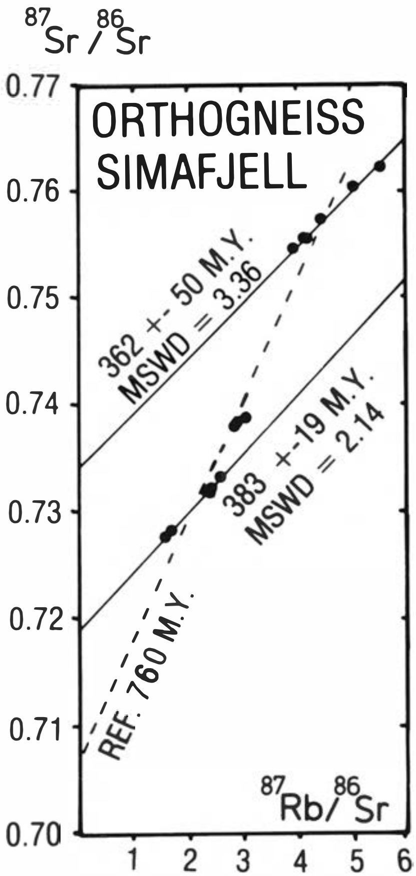

Fig. 4. Total rock Rb-Sr isochron diagram of the orthogneiss, Simafjell. Samples from locality 1 define the 383 ± 19 m.y. regression line. Samples from locality 3 define the 362 ± 50 m.y. regression line.

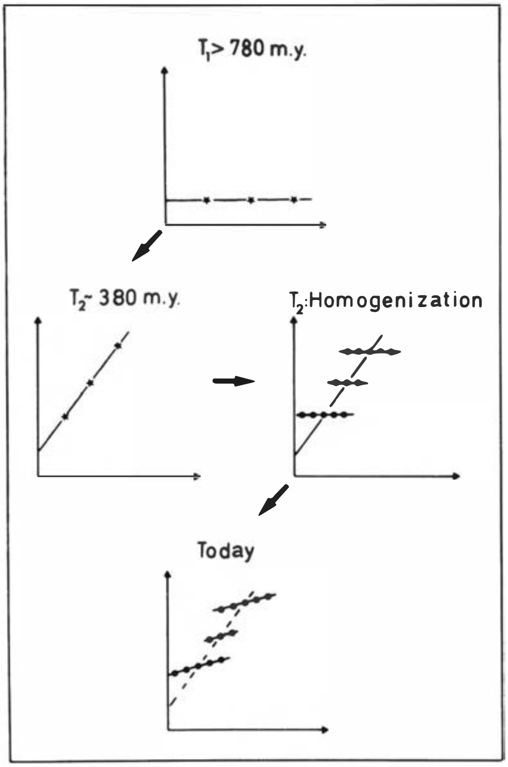

Fig. 5. Principal sketch showing the evolution of the isotope systems by isochron diagrams in the Simafjell orthogneiss. The first diagram illustrates the situation at T_1 (c. 760 m.y.) indicating the intrusion age or the first rehomogenization. The second and third diagram illustrate the situation at T_2 (c. 380 m.y.) indicating the second event which rehomogenized the rock in sub-systems. The last diagram illustrates the situation today represented by sub-parallel regression lines.

are significantly younger than the ages of the cross-cutting dykes. However, as the orthogneiss is deformed by F_1 and F_2 (strongly lineated) and has suffered the regional medium/high grade metamorphism we therefore conclude that the orthogneiss ages are secondary ages due to resetting of the Rb-Sr total rock isotope system at about 380 m.y.

The distribution pattern of the analyzed samples also supports this conclusion (Fig. 4). Two series define subparallel regression lines in the isochron diagram, with significantly different initial ratios. The sub-isochrons suggest that the rock was isotopically homogenized at least two times, once when the rock crystallized or recrystallized (intrusion or metamorphism) and a second time at about 380 m.y. The secondary event only rehomogenized parts or subsystems of the rocks, at least on the scale of each of the sampling sites investigated in this study.

A model age for the first homogenization of the orthogneiss has been calculated and is based on the following assumptions:

1) The orthogneiss was rehomogenized in subvolumes at least as big as the blocks or outcrops investigated.
2) Movement of Rb-Sr isotopes to or from the rehomogenized subvolumes can be ignored (see Fig. 3).
3) The orthogneiss as a whole remained a closed system during rehomogenization.

The model age is obtained by calculating

Rb/Sr for the samples in each series and the corresponding $^{87}Rb/^{86}Sr$ and $^{87}Sr/^{86}Sr$ from the regression lines for the sub-isochrons. The model age is 760 ± 120 m.y. (I.R. = 0.708 ± 0.005).

This age cannot be positively related to any geological event, but we suggest that it may be regarded as a lower time limit for the origin of the gneiss or a possible first homogenization of the orthogneiss caused by a metamorphic event. The model age supports previous geochronological evidence inferring that at least parts of the RNC and HNC are of Precambrian origin (Råheim & Ramberg 1982, Graversen et al. 1981, Cribb 1981). A sketch illustrating our model for interpretation of the isotopic pattern in the orthogneiss is shown in Fig. 5.

An interesting question is what may have caused the rehomogenization of the total rock systems at about 380 m.y. After the main metamorphism and deformation (F_1, F_2) the orthogneiss was affected by the two fold episodes (F_3, F_4). These late episodes formed the antiformal structure of the basement complex, and may be related to:

1) A late event of movement between the HNC and RNC (Gabrielsen & Ramberg 1979).
2) Thrusting of the HNC/RNC on top of Køli (e.g. Tveiten 1980).

Chloritization of biotite and garnet and new growth of white mica related to the F_3, F_4 events are recognized both in the orthogneiss and in the surrounding rocks (Brattli 1983). We suggest that the subisochron ages of about 360–380 m.y. may be related to the common retrogression effects which occurred during these events. Similar low grade retrogression effects involving migration of fluids have been shown to cause resetting of the total rock system elsewhere (Priem et al. 1978, Field & Råheim 1979a, Beckingsale et al. 1980, Page 1981). An important implication of this work is that resetting of total rock Rb-Sr systems must be taken into account when interpretations of such data are discussed. Sampling procedures may also, as shown, strongly affect the outcome of such studies.

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