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Isotopic age-determinations in Bergslagen, Sweden: VIII. Sveconorwegian Rb-Sr resetting and anomalous radiogenic argon in the Gothian Trans-Scandinavian Småland-Värmland Granitic Belt and bordering parts of the Svecokarelian Bergslagen Region

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Abstract

Biotite Rb-Sr data from 1.70–1.65 Ga old rocks of the Gothian Trans-Scandinavian Småland-Värmland Granitic Belt and from 1.90–1.84 Ga old rocks of the adjoining Svecokarelian Bergslagen Region indicate complete Sveconorwegian resetting 0.90 Ga ago, but a K-Ar analysis of the same biotites and of coexisting hornblendes yields significantly older ages. Some biotites and hornblendes have exceptionally high apparent ages, much older than those of the host rocks, pointing to the presence of excess radiogenic argon. The other K-Ar mineral ages are intermediate between the age of the host rocks and the 0.90 Ga old Sveconorwegian resetting. The hornblendes and biotites with intermediate ages show a weak positive correlation between radiogenic argon content and whole-rock potassium content. It is concluded that there was only limited mobility of radiogenic argon during the Sveconorwegian event. Apparently, the physicochemical conditions during Sveconorwegian recrystallisation were suitable for complete resetting of the Rb-Sr biotite systems, whereas the behaviour of radiogenic argon in the biotites and hornblendes was complex, leading to anomalous K-Ar dates.

Introduction

Southwestern Scandinavia (Fig. 1) forms a polyorogenic crustal segment showing the imprints of successively Proterozoic Gothian and Sveconorwegian metamorphism (e.g., Verschure 1985). It is an area characterized by vast stretches of monotonous gneisses, augengneisses, migmatites and granites with intercalated amphibolites, quartzites, marbles and subordinate amounts of low- to medium-grade sedimentary and volcanic supracrustal rocks. In this Gothian-Sveconorwegian area two major structural elements can be distinguished (e.g., Gorbatschev 1980; Verschure 1985):

1. to the East: the north-trending Trans-Scandinavian Småland-Värmland Granitic Belt, more than 1000 km in length and about 30 to 170 km wide, and
2. to the West: the Southwestern Gneiss Region, about 1000 km in length and up to 500 km wide.

Both structural elements have been initiated during the 'Early Gothian', as is testified by the great number of whole-rock Rb-Sr isochron ages in the range of 1.70 Ga to 1.65 Ga (e.g., Welin & Blomqvist 1966; Welin et al. 1966, 1977, 1982; Priem et al. 1970; Gorbatschev & Welin 1975, 1980; Skiöld 1976; Åberg 1979; Oen 1982).

The Trans-Scandinavian Småland-Värmland Granitic Belt, envisaged by Gorbatschev & Welin (1980) 'as a marginal manifestation of the Southwest Scandinavian crust-building processes along

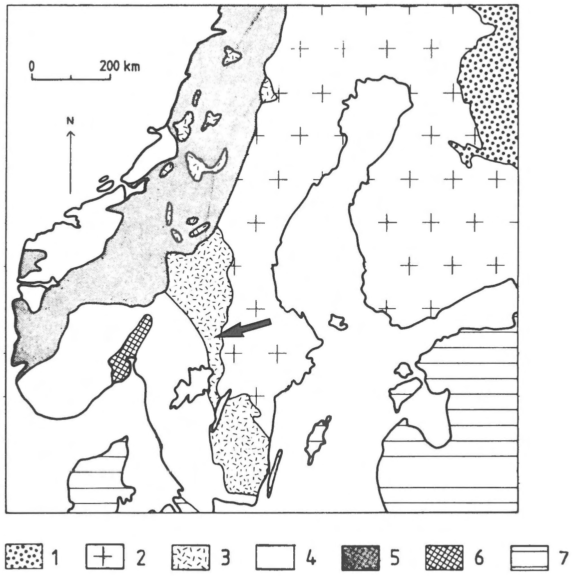

Fig. 1. Geological framework of southern Scandinavia (after Verschure 1985). (1) Archaean orogenic area (ages over about 2.50 Ga). (2) Svecokarelian orogenic area (ages between about 2.50 and 1.75 Ga. (3) Trans-Scandinavian Småland-Värmland Granitic Belt, Gothian-Sveconorwegian polyorogenic area (ages between about 1.70 and 0.85 Ga). (4) Southwestern Gneiss Region, Gothian-Sveconorwegian orogenic area (also ages between about 1.70 and 0.85 Ga). (5) Caledonian orogenic area (ages between about 0.60 and 0.30 Ga). (6) Oslo-Graben epeirogenic area (ages between about 0.25 and 0.20 Ga). (7) Autochthonous basement cover (ages of less than about 0.60 Ga). The arrow indicates the approximate location of the studied area.

the boundary of the then already stable Svecokarelian region', consists for the greater part of acid plutonic and volcanic rocks yielding exclusively Gothian whole-rock Rb-Sr ages between 1.70 Ga and 1.65 Ga. The Belt borders the Svecokarelian Bergslagen area and the northern extension is partly hidden underneath Caledonian overthrust nappes (e.g., Reymer et al. 1980). Its easternmost part shows Svecokarelian enclaves and embayments. Gothian acid volcanics are demonstrated to overlie unconformably Svecokarelian rocks (e.g., Lundqvist 1968). The Belt strikes obliquely to the Svecokarelian structures (Gorbatschev 1980; Nyström 1982). In the Southwestern Gneiss Region evidence for older continental crust, either Svecokarelian (2.50 Ga to 1.75 Ga) or not, has not yet been ascertained. The Southwestern Gneiss Region, dominated by gneisses and migmatites, displays a much wider age range than the Småland-Värmland Belt, i.e. both Gothian and Sveconorwegian Rb-Sr whole-rock ages, between 1.70 Ga and 0.85 Ga.

A major tectonic zone, the 'Sveconorwegian Front' (e.g. Gorbatschev, 1980) separates the Småland-Värmland Belt from the Southwestern Gneiss Region. The Sveconorwegian Front, as well as other major north-trending tectonic zones in southern Scandinavia, have evoked much global-tectonic speculation (e.g. Zeck & Mallin 1974; Torske 1977, 1985; Berthelsen 1980; Gower 1985). The original supposition (e.g., Wellin & Blomqvist 1966; Åberg 1979; Gorbatschev 1980) that the Sveconorwegian Front also forms the eastern limit of Sveconorwegian metamorphic mineral age resetting in southern Scandinavia, has been disproved by the discovery of Sveconorwegian mineral ages in Bergslagen, some 10 kilometers east of the eastern limit of the Småland-Värmland Belt (Verschure, 1981; Oen 1982). The Sveconorwegian influence reaches over the Sveconorwegian Front through the Småland-Värmland Belt into the Svecokarelian area. More to the east, in the Svecokarelian Hjulsjö region, there are no indications for Sveconorwegian resetting of Rb-Sr or K-Ar mineral ages (Moorman et al. 1981).

The present study reports the results of a Rb-Sr and K-Ar investigation of mineral age resetting in an west-east section from the Sveconorwegian Front, through the 1.70–1.65 Ga old Gothian Småland-Värmland Belt well into the 1.90–1.84 Ga old Svecokarelian Bergslagen area (Fig. 2). The investigated samples are from: (1) Svecokarelian metabasites (BRL 371, 372, 373, 374) that belong to the 1841 ± 55 Ma old Hyttsjö gabbro-tonalite suite (Oen & Wiklander 1982) and are situated in the Filipstad-Nordmark region which forms a Svecokarelian embayment in the Gothian Småland-Värmland Belt, (2) recrystallized Gothian granites of the Småland-Värmland Granitic Belt (BRL 469, 470, 471), (3) recrystallized gabbro-dioritic rocks (BRL 467, 468, 472) of the Småland-Värmland Granitic Belt, believed to be comagmatic with the Gothian granites of this Belt (Welin et al. 1977), (4) recrystallized Gothian granites from shear zones in

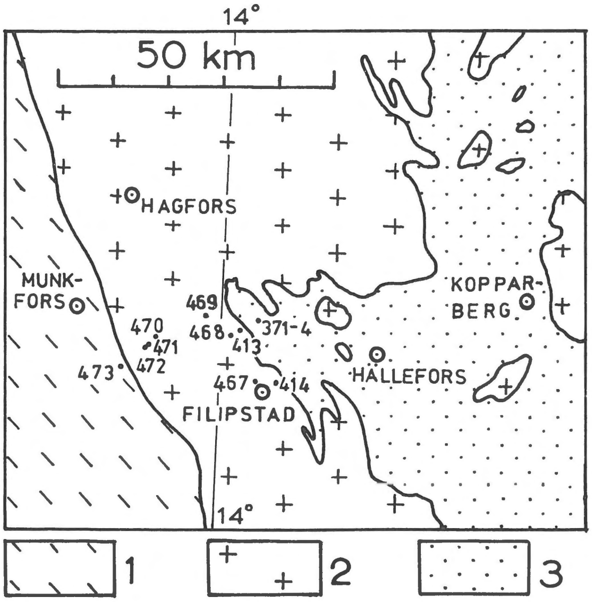

Fig. 2. Geological sketch map of the studied area in central Sweden. (1) Gneisses of the Gothian Southwestern Gneiss Region. (2) Granites and porphyries of the Gothian Trans-Scandinavian Småland-Värmland Belt and other granites of Gothian age. (3) Volcano-sedimentary succession and intrusive rocks of the Svecokarelian West Berglagen Region; the Filipstad-Nordmark area is situated North of Filipstad, the Hyttsjö area between Hällefors and Kopparberg. Sampling sites are indicated by the sample numbers.

the Småland-Värmland Belt (BRL 413 and BRL 414), and (5) an augengneiss (BRL 473) from the Sveconorwegian Front near the border between the Småland-Värmland Belt and the Southwestern Gneiss Region. Some petrographic and chemical data of the investigated rocks are given in Tables 2 and 3.

Experimental procedures and constants

Pure concentrates of hornblende and mica were separated from pulverized samples using large and small overflow-centrifuges employing sets of stabilized heavy liquids and a modified Frantz isodynamic magnetic separator (Verschure & IJlst 1966, 1969; IJlst 1973a, 1973b). Rubidium and strontium contents were measured by mass-spectrometric isotope dilution. Separation of rubidium and strontium was performed on cation exchange columns. Isotope measurements of rubidium and strontium were made with a computercontrolled Varian-Mat CH5 mass-spectrometer with Faraday cage collector and digital output ($^{87}Sr/^{86}Sr$ of the NBS-987 strontium carbonate standard measured as $0.71035 \pm 0.00028, 2\sigma$). The analytical precision is estimated to be within 0.5% for the isotope dilution analysis of rubidium and strontium and 0.04% for $^{87}Sr/^{86}Sr$. The potassium contents were determined by flame photometry with a lithium internal standard and caesium chloride-aluminium nitrate buffer. Argon was extracted in a bakeable glass vacuum apparatus and analysed by isotope dilution techniques in a Varian GD-150 mass-spectrometer; the measurements were made by the static method. The analytical accuracy is believed to be within 1% for potassium and 2% for radiogenic argon. These estimated overall limits of relative error are the sum of the known sources of possible systematic error and the precision of the total analytical procedures. For the age calculations the I.U.G.S recommended constants were used: $\lambda\ (^{87}Rb) = 1.42 \times 10^{-11} a^{-1}$, $\lambda_e(^{40}K) = 0.581 \times 10^{-10} a^{-1}$, $\lambda_\beta(^{40}K) = 4.962 \times 10^{-10} a^{-1}$ and abundance $^{40}K = 0.01167$ atom % total K.

Results and discussion

Table 1 shows that the four biotites from Svecokarelian rocks and the eight from Gothian rocks give biotite Rb-Sr model ages between 940 and 843 Ma. Regression of all Rb-Sr biotite data (Fig. 3) yields a 'reference isochron age' of 904 ± 31 Ma (MSWD = 9.6, initial $^{87}Sr/^{86}Sr = 0.701 \pm 0.078$, 2σ), i.e. substantially younger than the 1.90–1.84 Ga Svecokarelian and 1.70–1.65 Ga old Gothian rocks (whole-rock Rb-Sr ages). These results confirm the earlier observation (Verschure 1981; Oen 1982) that the Sveconorwegian metamorphic influence reaches through the Gothian Småland-Värmland Belt into the Svecokarelian Filipstad-Nordmark area. The resetting about 0.9 Ga ago of the Rb-Sr biotite systems is probably related to the observed non-equilibrium prehnite-pumpellyite-, greenschist- and amphibolite-facies

Table 1. Rb-Sr, K-Ar and K data of the investigated minerals, calculated Rb-Sr and K-Ar ages, excess radiogenic argon STP × 10^{-5} cc/g total Ar.

Sample Nr	Mineral	K (% Wt)	Rad.^{40}Ar STP × 10^{-5} cc/g total Ar	Calculated Age K-Ar (Ma)	Rb (ppm Wt)	Sr (ppm Wt)	^{87}Sr/^{86}Sr	Calculated Age Rb-Sr (Ma)[a]	Excess ^{40}Ar STP × 10^{-5} cc/g total Ar
79 BRL 371	Biotite	6.830* *	39.62* * *	1088 ± 40* * *	639.* *	8.69* *	4.4945* *	910 ± 10* *	5.255* *
	Hornblende	0.461	4.449	1562 ± 27					1.432* *
79 BRL 372	Biotite	7.675* *	62.34* *	1389 ± 25* *	405.* *	3.59* *	7.3366* *	860 ± 10* *	16.74* *
	Hornblende	0.821* *	5.943* * *	1280 ± 70* * *					1.348* *
79 BRL 373	Biotite	7.035* *	72.00* *	1625 ± 28* *	406.* *	5.52* *	4.1327* *	843 ± 10* *	24.37* *
	Hornblende	0.553* *	7.831* * *	1996 ± 60* * *					3.238* *
79 BRL 374	Biotite	6.800	59.74* * * *	1476 ± 80* * * *	405.* *	10.1* *	2.5996* *	1576 ± 80* *	21.65* * * *
	Hornblende	0.679* *	5.945* *	1463 ± 75* *					1.742* *
79 BRL 413	Biotite	8.125* *	41.35* * *	985 ± 50* * *	884.* *	6.60* *	10.930* *	924 ± 10* *	2.746* * *
79 BRL 414	Biotite	7.229* *	56.48* *	1352 ± 24* *	946.* *	6.59* *	12.298* *	913 ± 10* *	14.42* *
81 BRL 467	Hornblende	0.238* *	1.295* * * *	1038 ± 130* * * *					0.1305* * * *
81 BRL 468	Biotite	7.652* *	47.15* * * *	1138 ± 22* * * *	228.* *	9.15* *	1.7329* *	907 ± 10* *	7.559* *
	Hornblende	0.642* *	5.040* *	1356 ± 24* *					1.293* *
81 BRL 469	Biotite	7.707* *	134.2* *	2252 ± 70* *	606.* *	7.19* *	5.5681* *	940 ± 10* *	60.02* *
	Hornblende	1.035* *	12.36* * *	1796 ± 100* * *					4.663* * *
81 BRL 470	Biotite	7.678* *	43.15* * *	1963 ± 20* * *	1031.* *	9.84* *	7.2145* *	917 ± 10* *	5.086* * *
81 BRL 471	Biotite	7.493* *	106.4* * *	1999 ± 110* * *	350.* *	8.55* *	2.5068* *	906 ± 10* *	44.03* * *
	Hornblende	0.876* *	8.622* * *	1583 ± 45* * *					2.824* * *
81 BRL 472	Biotite	7.694* *	97.63* *	1865 ± 29* *	376.* *	9.55* *	2.4332* *	908 ± 10* *	38.12* *
	Hornblende	0.874* *	7.442* * *	1435 ± 45* * *					2.114* * *
81 BRL 473	Biotite	7.674* *	35.67* *	918 ± 18* *	415.* *	8.83* *	2.8021* *	898 ± 10* *	0.5390* *

* * = mean of 2 analyses
* * * = mean of 3 analyses
* * * * = mean of 4 analyses

[a] = initial ^{87}Sr/^{86}Sr is taken as 0.705

Table 2. Rocktypes with R_1–R_2 'De la Roche rock names', map grid-coordinates of the sampling sites, mineral composition of the samples in percentages.

Sample Nr.	Rocktype Fieldname and 'R_1-R_2 name'	Coordinates Rikets Nät System	Mineral composition and estimated amounts (%)																
			Qz	Plag	Kfs	Bi	Hbl	CPX	Chl	Ep	Sph	Cc	Ap	Zr	Ilm	Ort	Musc	Pump	Preh
79 BRL 371	Metabasite (gabbro-diorite)	FNV 8.0–33.6	10	05	–	05	60	–	–	03	03	–	<1	<1	03	–	–	–	–
79 BRL 372	Metabasite (gabbro-diorite)	FNV 7.9–33.9	10	15	<1	05	60	–	–	05	02	–	<1	–	02	<1	–	–	–
79 BRL 373	Metabasite (gabbro-diorite)	FNV 7.9–33.9	10	15	–	02	70	–	–	02	02	–	<1	–	03	–	–	–	–
79 BRL 374	Metabasite	FNV 7.9–33.9	05	10	–	05	70	–	–	01	02	–	<1	–	05	–	–	–	–
79 BRL 413	Granite mylonite (granite)	FNV 3.4–30.7	30	10	40	10	–	–	–	01	02	<1	<1	<1	<1	–	–	–	–
79 BRL 414	Granite mylonite (granite)	FNV 9.5–26.1	30	10	40	10	–	–	–	01	02	<1	<1	–	<1	–	–	–	–
81 BRL 467	Metagabbro (gabbro-norite)	FNV 3.8–26.2	<1	30	–	10	45	–	07	10	<1	–	<1	–	<1	–	–	–	–
81 BRL 468	Metagabbro (gabbro-diorite)	FNV 1.8–29.0	02	40	–	25	20	–	–	10	01	<1	01	–	–	<1	–	–	–
81 BRL 469	Metagranite (tonalite)	MNO 34.4–96.7	20	40	20	06	06	–	–	05	02	–	<1	<1	<1	–	01	<1	–
81 BRL 470	Metagranite (granite)	MNO 29.7–89.7	20	10	50	10	06	–	–	<1	–	–	<1	<1	03	<1	<1	–	–
81 BRL 471	Metagranite (monzonite)	MNO 28.2–87.1	10	60	10	10	05	–	–	02	0.5	–	<1	<1	0.5	–	–	<1	–
81 BRL 472	Metadiorite	MNO 27.1–84.4	10	45	–	10	20	05	–	05	<1	–	<1	<1	–	–	–	<1	<1
81 BRL 473	Augengneiss (quartz-monzonite)	MNO 26.3–83.2	10	45	–	10	20	–	–	05	<1	–	<1	<1	05	<1	–	–	–

FNV = Sheet Filipstad NW (topographical map of Sweden 1 = 50,000)
MNO = Sheet Munkfors NE ibid.

Qz = quartz; Plag = plagioclase; Bi = biotite; Hbl = hornblende; CPX = clinopyroxene; Chl = chlorite; Ep = epidote; Sph = sphene; Cc = calcite; Ap = apatite; Zr = zircon; Ilm = ilmenite; Ort = orthite; Musc = muscovite; Pump = pumpellyite; Preh = prehnite.

Table 3. Whole rock analyses of some of the investigated samples presented as main element oxide percentages and their R_1-R_2 multicationic values. $R_1 = 4\,Si - 11(Na + K) - 2\,(Fe + Ti)$; $R_2 = 6\,Ca + 2\,Mg + Al$ (De la Roche et al. 1980).

	79 BRL 371	79 BRL 372	79 BRL 373	79 BRL 413	81 BRL 467	81 BRL 468	81 BRL 469	81 BRL 470	81 BRL 471	81 BRL 473
SiO_2	49.67	50.35	50.12	69.99	46.71	54.76	64.52	66.255	57.46	61.75
TiO_2	01.458	02.001	01.574	00.360	00.246	00.715	00.707	00.515	00.741	00.628
Al_2O_3	12.61	11.88	12.43	14.46	17.30	18.02	16.52	15.64	19.37	17.71
Fe_2O_3	16.80	19.00	17.24	03.183	08.740	08.062	05.163	03.640	05.758	04.752
MgO	05.56	03.75	05.00	00.325	11.1	04.28	01.56	01.15	02.14	01.60
CaO	09.416	07.667	08.951	01.517	10.79	07.378	04.009	02.350	05.158	03.958
MnO	00.242	00.271	00.258	00.057	00.139	00.140	00.102	00.096	00.127	00.131
Na_2O	01.69	02.00	02.64	02.97	01.28	03.19	03.65	03.67	04.42	04.66
K_2O	00.6348	01.065	00.7473	05.778	00.7728	01.968	04.009	04.766	03.212	03.361
P_2O_5	00.158	00.422	00.91	00.085	00.041	00.207	00.225	00.187	00.293	00.239
R_1	2104	1858	1753	2161	2257	1829	1959	1899	1341	1545
R_2	1531	1241	1492	462	2041	1357	828	617	1038	853

mineral assemblages observed in these rocks (Table 2). The apparent K-Ar mineral ages of the Svecokarelian and Gothian rocks show a large spread, ranging from 918 to 2252 Ma for the biotites and from 1036 to 1966 Ma for the hornblendes. All biotites and hornblendes have apparent K-Ar ages older or much older than the biotite Rb-Sr reference isochron age. For three rocks (BRL 469, 471, 472) the biotite K-Ar ages even exceed the corresponding whole-rock age, as is also the case with the hornblende ages of BRL 373 and 469 (Fig. 4). Even samples collected in a restricted area (e.g., BRL 371, 372, 373, 374) from a metabasite body belonging to the 1841 ± 55 Ma old Svecokarelian Hyttsjö gabbro-tonalite suite (Oen & Wiklander 1982) show a significant spread in the biotite and hornblende K-Ar dates.

Such erratic response of the biotite-hornblende K-Ar system to the same PTX conditions in comparison with the biotite Rb-Sr system, can be explained in terms of a complete or partial escape or introduction of radiogenic argon out of or into the crystal lattices of minerals that are undergoing recrystallization. In this respect structural conversions, for example polymorphic changes of minerals such as betrayed by DTA and TGA, merit to be considered. Potassium gain or loss do not seem to be significant factors in view of the limited variation in potassium content (6.800 to 8.125 Wt % for biotite and 0.238 to 0.876 Wt % for hornblende) in comparison with the large variation in the radiogenic argon content (134.2 to 35.67 × 10^{-5} cc STP/g for biotite and 12.36 to 1.295 × 10^{-5} cc STP/g for hornblende). For K-Ar mineral ages lower than the whole-rock age, the possibilities of introduction or partial retention of radiogenic argon are difficult to evaluate. The amount of radiogenic argon that might be introduced or retained in a crystal lattice during resetting depends mainly on two factors: (1) the presence and abundance of argon-donating potassium-bearing mineral phases with relatively low argon-retention temperatures, and (2) the time-span during which radiogenic argon has been accumulated. In geochronology the openness of the crystal lattice to radiogenic isotopes is mainly considered in relation to temperature, and is therefore expressed in terms such as

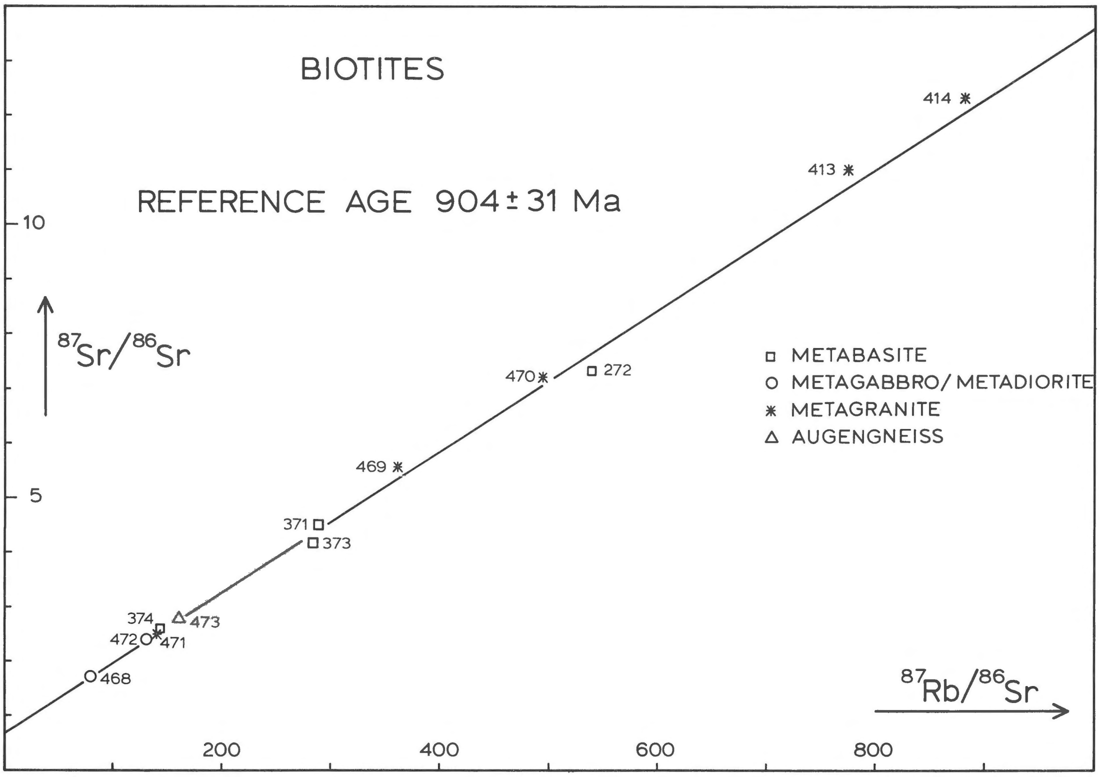

Fig. 3. Regression of biotite Rb-Sr data in a Nicolaysen plot.

retention temperature, closing temperature, blocking temperature and temperature of resetting. However, it becomes increasingly clear that other factors also play an important role, for example transporting agents, element concentration in the transporting agents, pathways for transport, pressure gradients, and time.

closing temperature, blocking temperature and temperature of resetting. However, it becomes increasingly clear that other factors also play an important role, for example transporting agents, element concentration in the transporting agents, pathways for transport, pressure gradients, and time.

A comparable case has been described by Foland (1979, 1983), who proposed a model to explain the varying amounts of excess argon in Rb-Sr reset biotites of the granulite facies metamorphosed Arden pluton of the Wilmington complex, Appalachian Piedmont, U.S.A. This model implies that the excess radiogenic argon in biotite is of local derivation released during heating from potassium-bearing minerals with relatively low blocking temperatures (for example potassium feldspar) in the immediate vicinity of the biotites. When the ambient temperature rises above the blocking temperature of various minerals, the radiogenic argon is liberated. It is supposed by Foland that this released argon remains occluded in the rock, concentrated along grain-boundaries, cracks, crystal imperfections, etc., mainly because of the absence of water-dominated fluids that could serve as transport medium. Foland's model is based on the observation that the concentrations of total argon in the biotites show a good linear correlation with the corresponding whole-rock potassium contents, implying that argon mobility during the dry granulite facies metamorphism of the Arden pluton was restricted to a scale of a few meters at most. The volume of argon incorporated in the minerals is controlled by the specific capacities of the different minerals to take up argon, and by the ambient

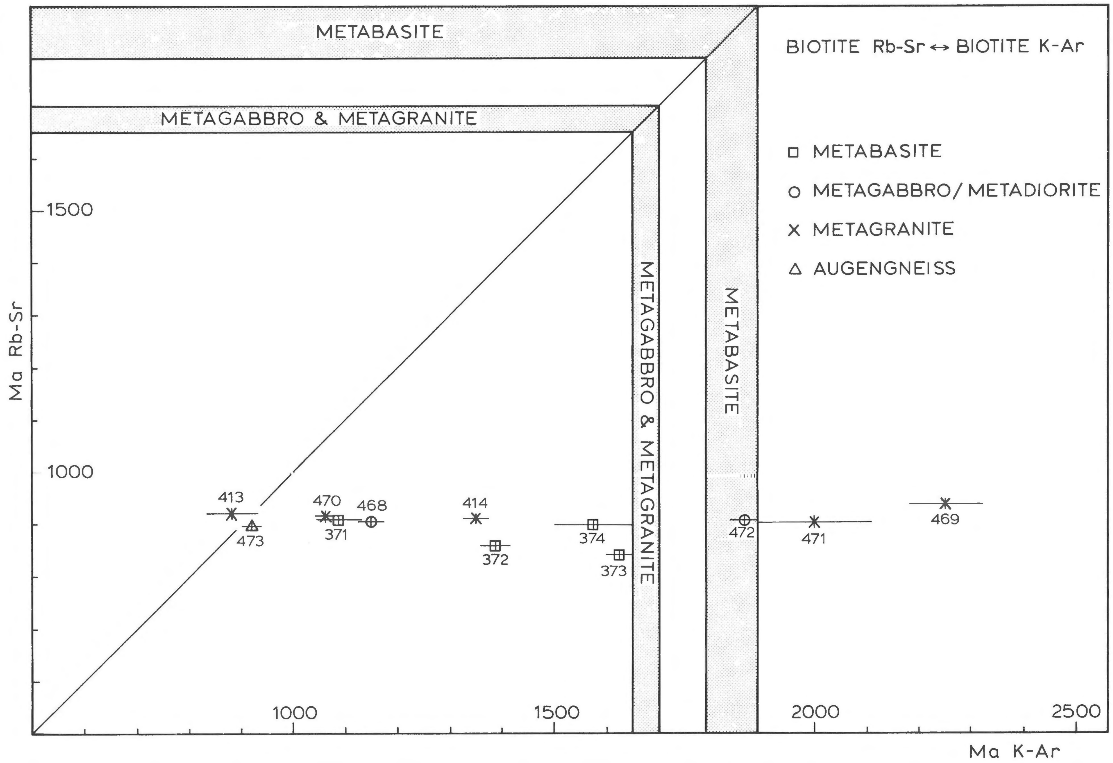

Fig. 4. Relationship between Rb-Sr model ages and apparent K-Ar ages of the biotites. Stippled areas refer to the emplacement ages of the Svecokarelian and Gothian intrusive rocks.

argon pressures. According to this model excess radiogenic argon in reset minerals should be common in polymetamorphic rocks where PTX conditions during the subsequent metamorphic phases have prevented the radiogenic argon to migrate out of the rocks. This model is in fact consistent with experiments showing that muscovite subjected to argon pressures at high temperatures can incorporate significant amounts of argon (Karpinskaya et al. 1961), and with observations indicating the presence of occluded argon in rocks (argon in fluid inclusions, varying argon concentrations in different parts of crystals).

For the Gothian and Svecokarelian rocks in central Sweden, the amount of excess radiogenic argon in each biotite and hornblende can be calculated on the presumption that the mineral K-Ar systems closed 900 Ma ago (Table 1). The volumes of excess radiogenic argon in the biotites, calculated by correcting for 900 Ma of in situ produced radiogenic argon, vary strongly, even between close-spaced samples (for example the biotites BRL 371 and 373, with excess radiogenic argon contents of 5.255×10^{-5} cc STP/g and 24.37×10^{-5} cc STP/g, respectively). The excess radiogenic argon contents of the biotites are exceptionally high when compared to published data (Dalrymple & Lanphere 1969). The amounts of excess radiogenic argon in the hornblendes also vary over orders of magnitude (0.131×10^{-5} cc STP/g to 4.663×10^{-5} cc STP/g). Furthermore, large volumes of excess argon in biotite are generally coupled to large volumes of excess argon in the associated hornblendes. All these data strongly suggest that both the biotite and the hornblende structures can accommodate relatively large amounts of argon, but that the actual amount of excess argon that is incorporated depends on the partial argon pressure in the immediate vicinity of the minerals.

The investigated rocks display no correlation between excess radiogenic argon in the biotites and hornblendes on the one hand, and the whole-rock potassium contents on the other hand. This lack in correlation can be understood when taking into account that, at similar potassium contents, the older Svecokarelian rocks have a higher potential for radiogenic argon than the younger Gothian rocks. Also, the samples are spread over a large region, so that an identical PTX-history cannot be assumed, even for consanguineous rocks. However, both biotite and hornblende show a weak correlation of 0.7 between the excess radiogenic argon and the whole-rock potassium contents, when only those biotites and hornblendes are considered that have apparent ages intermediate between the age of the host rock and the 0.9 Ga old Sveconorwegian resetting. This suggests, as in the case of the Wilmington complex, a very restricted argon mobility in the whole investigated area throughout geological history.

Concluding remarks

The erratic K-Ar mineral ages in Svecokarelian and Gothian rocks that have undergone Sveconorwegian metamorphism are attributed to the restricted mobility of radiogenic argon as a consequence of the non-equilibrium, relatively dry metamorphism. The metamorphic conditions, with limited availability of fluid transport media, apparently permitted the equilibration of radiogenic strontium that was released from the biotites during recrystallization or polymorphic modification. In this context it may be relevant to call attention to the experimentally induced migration of rubidium, strontiun, potassium and sodium between various mineral constituents in a large adamellite sample that was subjected to simple dry heating (Baadsgaard & Van Breemen 1970). It is possible that the limited amounts of available fluids already present in the rock (fluid inclusions, OH-radicals etc.) permit the transport of released radiogenic strontium and isotopic homogenization of strontium between the relevant mineral phases, but that these fluids are unable to transport argon gas out of large rock volumes. In the investigated area such conditions may have led to strong gradients of ambient argon pressures, resulting in anomalous biotite and hornblende K-Ar ages.

The results presented in this paper show that the response of the biotite Rb-Sr system to metamorphism is relatively straightforward, with uniform ages indicative of the resetting event, whereas the response of the biotite and hornblende K-Ar systems to the same conditions often leads to anomalous ages. The phenomena discussed here are probably not limited to the investigated section through the Småland-Värmland Belt and adjacent Svecokarelian terrains, but may be widespread in the whole Western Gneiss Region of southern Scandinavia.

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