A reconnaissance Rb-Sr study of Precambrian rocks from the Sjangeli-Rombak window and the pattern of initial $^{87}Sr/^{86}Sr$ ratios from northern Scandinavia

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Coarse-grained granitic rocks underlie the Caledonian series in the Sjangeli-Rombak window, North Norway. A Rb-Sr whole-rock isochron on these granites gives a date of about 1780 Ma. The initial $^{87}Sr/^{86}Sr$ ratio of 0.700 + 0.006 suggests that the granites were derived from the mantle or from an isotopically similar region without significant incorporation of sialic material. The distribution of published initial ratios for crystalline rocks in North Norway and Sweden dated between 1845 and 1535 Ma is consistent with the existence of an eastward-dipping NW-SE trending subduction zone beneath the area during this period.

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The Sjangeli-Rombak window is an area of pre-Caledonian rocks within the main Caledonian belt south-east of Narvik, North Norway (Fig. 1). There is no complete account of the geology of the window.

Gustavson's accounts (1966, 1969, 1972) of the regional geology include descriptions of the Norwegian part. Parts have been mapped by Vogt (1941, 1950) and Birkeland (1976) in Norway, and by Kulling (1964) in Sweden. Fig. 2 is a simplified compilation of their maps. Table 1 summarises the main events in the geological history of the area.

A reconnaissance Rb-Sr study of the coastal region to the west included analyses of granitic rocks from the Rombak window (Heier & Compston 1969) which suggest that the rocks were formed at least 1670 Ma ago. Migmatitic gneisses from Vesterålen, 100 km north-west of the Sjangeli-Rombak window, have been dated at about 2700 Ma (Griffin et al. 1978).

The present study was undertaken with three objectives: to clarify the history of the major granitic bodies in the Sjangeli-Rombak window; to determine the age of pegmatite and aplite dykes that intrude them; and to date the supracrustal series which forms the oldest known rock unit in the window.

A total of 25 whole-rock samples were analysed for this study (Table 2). The granitic rocks (11 samples) vary in composition from granodiorite to granite. The dykes comprise aplites and K-feldspar-rich pegmatites, both having subordinate contents of biotite and white mica. The supracrustal rocks are mostly dark fine- to medium-grained rocks, generally greenish. Their textures vary from massive to well-foliated. They have been subjected to folding and low-grade metamorphism. Their parent rocks were probably volcanic or hypabyssal types with compositions ranging from basic to acid.

Analytical methods

Samples were analysed for Rb and Sr by standard isotope dilution techniques, using spikes enriched in ^{87}Rb and ^{84}Sr respectively. Isotopic analyses were carried out at Cambridge University using an Atlas CH4 mass spectrometer equipped with peak switching and punched paper tape digital output. All measured values of the $^{87}Sr/^{86}Sr$ ratio were corrected for isotopic fractionation to $^{86}Sr/^{88}Sr = 0.1194$. Isochrons were fitted by the method of York (1969). Ages were calculated using a value of $1.42 \cdot 10^{-11} a^{-1}$, and in citing the literature all Rb-Sr ages have been recalculated using this decay constant. Six analyses of N.B.S. isotope standard 987 carried out in the Cambridge laboratory during the period covering this study give a mean corrected $^{87}Sr/^{86}Sr$ ratio of 0.71053.

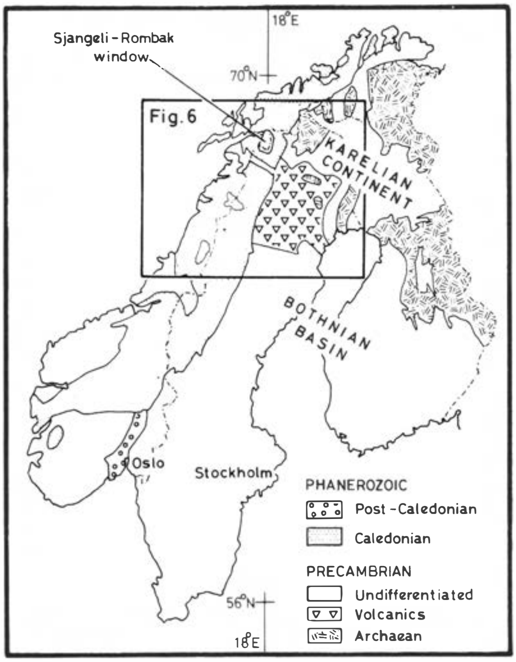


Fig. 1. Map of Fennoscandia showing distribution of major rock series and locations of main pre-Caledonian windows. After Wilson & Nicholson (1973) and Adamek & Wilson (1979).

Table 1. Major geological events in the Sjangeli-Rombak window

(6) *Caledonian Tectonic Phase*
Large-scale eastward thrusting of the sedimentary pile (See 5). Regional metamorphism, principally affecting its upper portions. Precambrian basement locally sheared but largely unaffected by metamorphism.

(5) *Depositional Phase*
Deposition of Upper Precambrian (?) and Lower Palaeozoic detrital sediments resting on a basal conglomerate, locally autochthonous.

(4) *Minor Intrusive Phase*
Emplacement of pegmatite and aplite dykes and sheets.

(3) *Major Intrusive Phase*
Emplacement of extensive bodies of granite, preceded by smaller bodies of syenite and locally gabbro. Incorporation of supracrustal rocks as inclusions in granite. Regional metamorphism of remnants of supracrustal series up to amphibolite facies.

(2) *Folding*
Widespread folding of the suppracrustal series, giving predominantly steep dips. Axes generally NNE-SSW.

(1) *Formation of the Supracrustal Series*
Extrusion of volcanic rocks, dominantly basic. Deposition of sediments, largely argillaceous, with some carbonates.

Results and interpretation

Granites

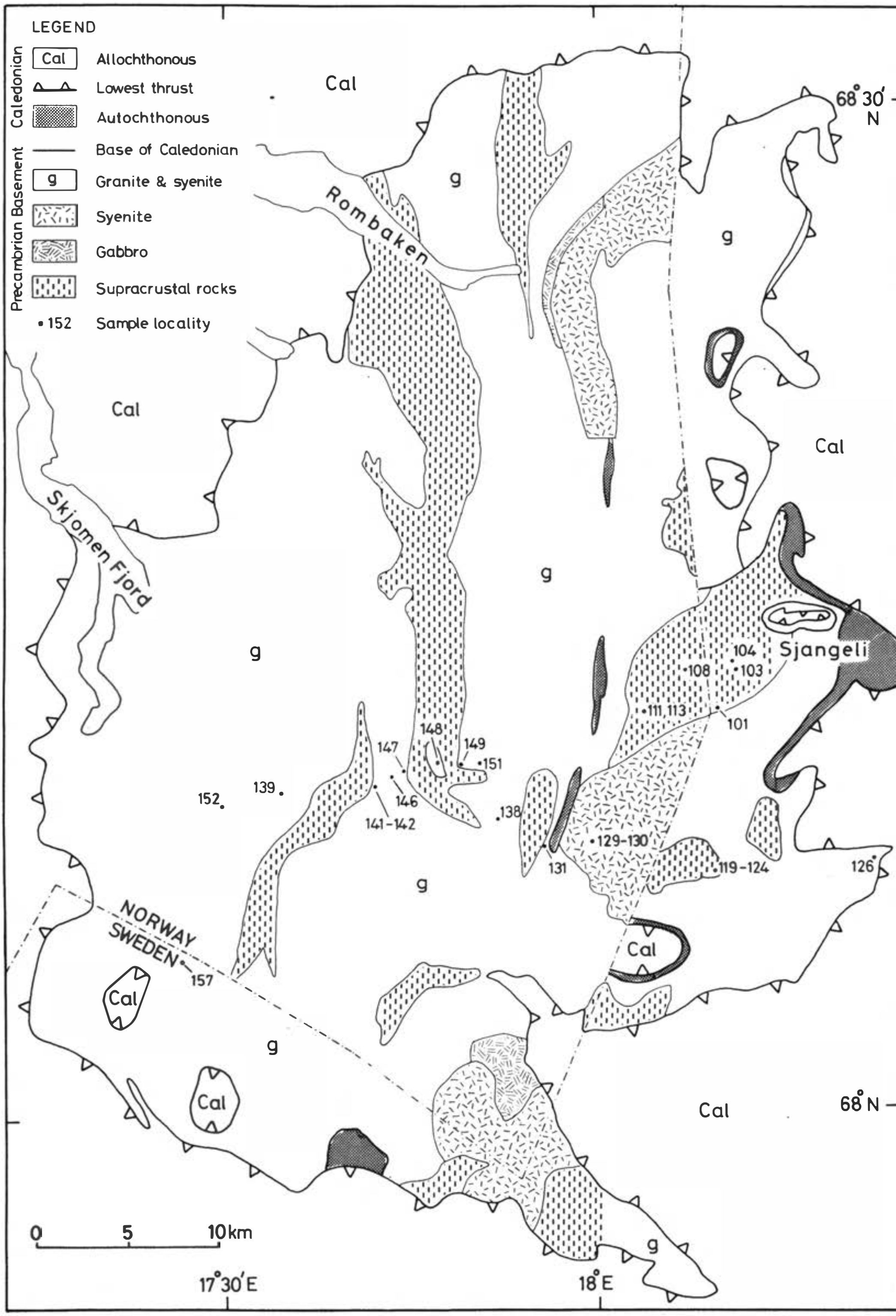
The 11 granite samples form a linear array on the Rb-Sr isochron diagram (Fig. 3). A straight-line isochron fitted to the points indicates a date of 1780 ± 85 Ma. The points do not all lie within the analytical uncertainty of this line. The mean square of the weighted deviates is 34.1. Increasing the errors by a factor of six produces a perfect fit.

The data presented here (11 samples) and the results of the previous Rb-Sr isochron study of granitic rocks from the Sjangeli-Rombak window (Heier & Compston 1969, 4 samples) do not differ significantly. Both the dates, 1780 ± 85 and 1691 ± 90 Ma, and initial $^{87}Sr/^{86}Sr$ ratios, 0.700 ± 0.006 and 0.706 ± 0.002 (computed from data in Heier & Compston 1969, Table 11), differ by less than the sum of the quoted errors.

There are three possible interpretations for these results: (1) The rocks crystallised from a common parent magma, and the date of 1780 Ma records the time elapsed since the rocks became closed to Rb and Sr following crystallisation; (2) The rocks were derived from the ultrametamorphism of a pre-existing crustal complex whose overall composition was granitic. This event caused complete homogenisation of Sr isotopes between the rocks analysed, and the data records the time elapsed since; (3) The rocks crystallised as granitic intrusives at some time prior to about 1780 Ma ago, when regional metamorphism reset their Rb-Sr systems (cf. Skiöld & Larsson 1978, Åberg 1978).

The available geological evidence is too limited to give unequivocal support to one model. However, the low value of the initial $^{87}Sr/^{86}Sr$ ratio together with the relatively high Rb/Sr ratios suggest that the parent material of the granite, of whichever type, did not reside in the sialic crust for any significant period before about 1780 Ma ago. It may instead have been derived from the mantle (or a region with a comparable Sr isotopic composition) shortly before that time.

Fig. 2. Simplified geological map of the Sjangeli-Rombak window, showing locations of rocks sampled for this study. Geology after Vogt (1950) and Birkeland (1976).


LEGEND
Caledonian
Cal Allochthonous
Lowest thrust
Autochthonous
Precambrian Basement
Base of Caledonian
g Granite & syenite
Syenite
Gabbro
Supracrustal rocks
• 152 Sample locality
Cal
g
Rombaken
Skjomen Fjord
Sjangeli
NORWAY
SWEDEN
68°30' N
68° N
17°30'E
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0 5 10km
104
103
108
111, 113
101
147
148
149
151
146
141-142
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152
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129-130
131
119-124
126
157

Table 2. Descriptions and Rb-Sr analyses of rocks from the Sjangeli-Rombak window

Sample	Rock type	Average[1] grain size	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
	Granites					
126	Leucocratic granite	m	152	165	2.70	0.7564
130	Leucocratic granite, as dyke cutting syenite	m	139	86.5	4.75	0.8355
131	Equigranular biotite granite	m	138	492	0.821	0.7333
138	Biotite granite, somewhat foliated	c	244	126	5.70	0.8348
139	Biotite granite, somewhat foliated	c	195	180	3.19	0.7668
141	Biotite granite, somewhat foliated	c	355	112	9.46	0.9418
147	Leucocratic biotite granite	m	347	55.4	19.2	1.207
148	Biotite granite, strongly porphyritic	c	231	123	5.58	0.8508
151	Leucocratic granite, as dyke cutting foliated biotite syenite	c	182	93.5	5.76	0.8462
152	Biotite granite, weakly foliated	c	341	117	8.72	0.9153
157	Biotite granite, foliated	m-c	347	120	8.65	0.9229
	Pegmatites					
119	Quartz-microcline rock, 3–4 m thick dyke intruding syenite	vc	413	19.0	87.0	1.903
120	Quartz-microcline rock, >2 m thick dyke intruding greenstone	vc	53.8	15.7	10.3	0.9683
124	Quartz-microcline rock, dyke intruding greenstone	vc	415	21.3	63.2	1.839
129	Quartz-microcline rock, > 2 m thick dyke intruding foliated syenite	vc	259	18.9	42.7	1.297
146	Quartz-microcline rock, dyke intruding granite	vc	123	33.9	10.9	1.013
	Aplites					
121	Foliated quartz-feldspar rock, 0.75 m thick sheet concordant with foliation in greenstone	m	43.0	1480	0.085	0.7195
142	Unfoliated quartz-feldspar rock, dyke intruding granite, associated with pegmatite dyke	m	335	36.3	19.1	1.038
	Supracrustal Rocks					
101	Greenish black epidote-hornblende-feldspar rock, cut by epidote-bearing veinlets up to 2 mm thick	f-m	164	238	2.02	0.7351
103	Grey epidote-plagioclase rock, interlayered with biotite schist	f	8.46	137	0.182	0.7163
104	Dark green epidote-hornblende-feldspar rock, unfoliated	f-m	10.9	59.0	0.555	0.7298
108	Green hornblende-feldspar rock	f-m	81.1	128	1.86	0.7433
111	Green chlorite-epidote-feldspar rock, somewhat foliated, interlayered with chlorite schist	f-m	79.8	446	0.523	0.7111
113	Grey quartz-feldspar rock, unfoliated	m	28.9	656	0.129	0.7138

[1]f = fine-grained, m = medium-grained, c = coarse-grained, vc = very coarse-grained.

Pegmatite and aplite dykes

The 7 sample analyses are plotted on a Rb-Sr isochron diagram in Fig. 4. The points form a diffuse band and no isochron can be fitted to them. If the samples are co-magmatic, reference isochrons A (1150 Ma) and B (625 Ma) may indicate maximum and minimum ages for them. In this case their isotopic systems have been disturbed, in the Late Precambrian or during Caledonian events, or both.

Supracrustal series

When plotted on a Rb-Sr isochron diagram (Fig. 5) the 6 samples show no simple distribution pattern. No clear conclusions can be drawn, particularly since the number of samples is small. If one assumes that the rocks are volcanic and co-magmatic, then evidently they have not remained closed systems with respect to Rb and Sr.

Geological evidence (Table 1) indicates that the supracrustal series in the Sjangeli-Rombak window predates the emplacement of the granites represented by the 1780 Ma isochron. Similar supracrustal rocks, interpreted as older than adjacent granites, have been reported from adjacent parts of Sweden (Adamek 1975). One might expect at least partial open system behaviour in the supracrustal rocks during the granite emplacement. The isotopic disturbance may have occurred then or during later Sveconorwegian or Caledonian events.

Svecofennian Rb-Sr data from northern Scandinavia

Pattern of initial $^{87}Sr/^{86}Sr$ ratios

Rocks giving Rb-Sr isochron ages between about 2000 and 1500 Ma occur in northern Sweden and in the pre-Caledonian basement of northern Norway (Heier & Compston 1969, Welin et al. 1970, Brueckner 1971, Welin et al. 1971, Gulson 1972, Wilson & Nicholson 1973, Skiöld 1976 & 1977, Welin et al. 1977, Griffin et al. 1978, Skiöld & Larsson 1978, Reymer 1979, Råheim et al. 1979, Skiöld 1979, Andresen 1980). Welin (1970) discussed the evolution of the Svecofennian orogeny and Lundqvist (1979) reviewed the Precambrian of Sweden. Wilson & Sundin (1979) compiled radiometric age determinations between 1960 and 1978 for Swedish rocks and minerals, and Wilson (1980) discussed the classification of Swedish Precambrian granites.

Table 3 lists published results for 40 Rb-Sr isochrons on igneous and gneissic rocks from northern Scandinavia. Of these, 6 give ages in the 'primorogenic' range 2000 to 1800 Ma, 8 give 'synorogenic' ages between 1800 and 1745 Ma, and 26 give 'post-orogenic' ages between 1745 and 1500 Ma.

The geographical distribution of dates shows no apparent pattern, but the initial ratios of the syn- and post-orogenic rocks together differ in the western and eastern parts of the region (Fig. 6). An arcuate transition zone trending N-S in the Narvik-Tromsø area and more nearly E-W near Luleå separates these two areas.

In the western area the initial ratios of rocks from all three age groups vary from 0.700 to 0.706. In the transition zone the majority of the ratios are in the range 0.700 to 0.708. One rock unit only, the Guorbavare granite, has a higher ratio (0.712). In the eastern area the majority of the ratios are in the range 0.707 to 0.716. Only two rock units have lower ratios: the primorogenic Paittasjärvi granodiorite (0.703) and the post-orogenic Kiruna volcanics (0.705). In each of the three areas, the post-orogenic rocks generally have the highest ratios and the primorogenic rocks the lowest ones.

The rocks listed in Table 3 could have been derived from three types of source region: the

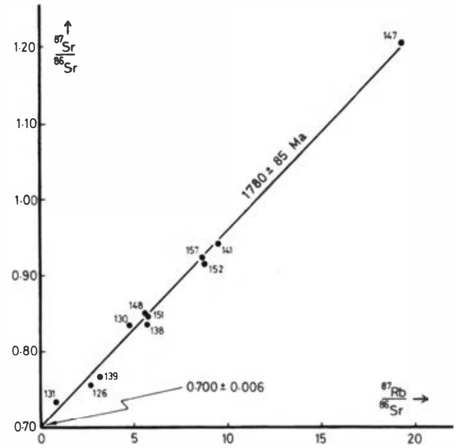

Fig. 3. Whole-rock isochron plot for granites from the Sjangeli-Rombak window.

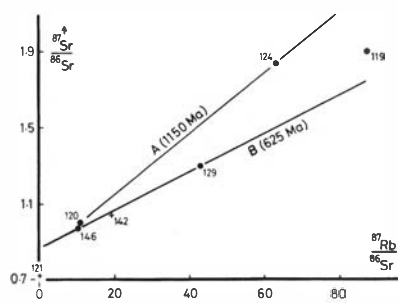

Fig. 4. Whole-rock isochron plot for pegmatite (dots) and aplite (crosses) dykes from the Sjangeli-Rombak window. A and B are reference isochrons.

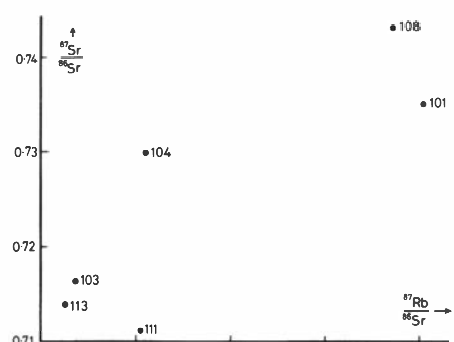

Fig. 5. Whole-rock isochron plot for supracrustal rocks from the Sjangeli-Rombak window.

Table 3. Rb-Sr whole – rock isochron data for Svecofennian igneous and gneissic rocks, north Norway and north Sweden

Number	[1]Age(Ma)	[2]I.R.	Rock unit	Notes	Source
1	1915 ± 145	0.7032 ± 0.0005	Granodiorite, Lake Paittasjärvi		Skiöld 1979
1A	1884 ± 120	0.7033 ± 0.0006	Novijaur granodiorite		Skiöld & Larsson 1978
1B	1875 ± 20	0.7025 ± 0.0007	Juoksjokko granite		Skiöld & Larsson 1978
2	1825 ± 40	0.706 ± 0.002	Haparanda suite		Welin et al. 1970
3	1805 ± 20	0.7032 ± 0.0003	Austvagøy grey mangerite,[3] L-V		Griffin et al. 1978
4	1800 ± 50	0.7033 ± 0.0006	Sund-Ølkona mangerite, L-V		Griffin et al 1978
5	1790 ± 50	0.7046 ± 0.0007	Hopen mangerite & charnockite, L-V		Griffin et al 1978
6	1780 ± 85	0.700 ± 0.006	Granite, Sjangeli-Rombak window		This paper
7	1780 ± 50	0.707 ± 0.005	Lina granite, E. Norrbotten, Sweden		Welin et al. 1971
8	1777 ± 90	0.702 ± 0.004	Granite. Svolvær. L-V		Heier & Compston 1969
9	1772 ± 40	0.7050 ± 0.003	Degerberg granite, Kalix		Skiöld 1977
10	1772 ± 20	0.7051 ± 0.0004	Red granite, Kalix		Skiöld 1977
11	1770 ± 70	0.7046 ± 0.0008	Hamarøy basic mangerite, L-V		Griffin et al. 1978
12	1747 ± 40	0.707 ± 0.002	Revsund granite, Lycksele	whole-rock & mineral isochron	Welin et al. 1971
13	1742 ± 43	0.703 ± 0.002	Granitic gneiss, Nasafjäll		Wilson & Nicholson 1973
14	1742 ± 30	0.705 ± 0.002	Granite, Arvidsjaur		Welin et al. 1977
15	1735 ± 25	0.7041 ± 0.0002	S.W. Lofoten mangerite		Griffin et al. 1978
16	1735 ± 30	0.7050 ± 0.0003	Lundøy mangerite & orthogneiss, L-V		Griffin et al. 1978
17	1733 ± 25	0.705 ± 0.001	Granite, Adak		Welin et al. 1977
18	1730 ± 40	0.7030 ± 0.0002	Steine mangerite, L-V		Griffin et al. 1978
19	1713 ± 40	0.716 ± 0.002	Granite, Vuolosjärvi-Vakkojärvi		Welin et al. 1971
20	1710 ± 60	0.7046 ± 0.0005	Raftsund mangerite, L-V		Griffin et al. 1978
21	1706 ± 15	0.7040 ± 0.0003	Ersfjord granite, W. Troms		Andresen 1980
22	1705 ± 30	0.7051 ± 0.0003	Raftsund mangerite, L-V		Griffin et al. 1978
23	1698 ± 25	0.708 ± 0.002	Hällnäs granite, Skellefte		Welin et al. 1977
24	1695 ± 15	0.7043 ± 0.0003	Hamarøy acid mangerite & charnockite, L-V		Griffin et al. 1978
25	1694 ± 73	0.705 ± 0.003	Granitic gneiss, Glomfjord		Wilson & Nicholson 1973
26	1690 ± 75	0.703 ± 0.005	Duobblon acid volcanics, Sorsele		Welin et al. 1971
27	1679 ± 90	0.706 ± 0.002	Granite, syenite & aplite, Sjangeli-Rombak window	I.R. calculated from data in source	Heier & Compston 1969
28	1669 ± 45	0.704 ± 0.007	Gneiss, Red granite etc., L-V		Heier & Compston 1969
29	1667 ± 80	0.706 ± 0.004	Torset granite, Langøy, L-V		Brueckner 1971
30	1653 ± 84	0.704 ± 0.001	Basement gneiss, Grong		Råheim, Gale & Roberts 1979
31	1645 ± 35	0.708 ± 0.005	Ledfat granite, Skellefte		Welin et al. 1977
32	1600 ± 90	0.714 ± 0.005	Acid volcanics, Kaska Tjaurek		Welin et al. 1971
33	1570 ± 65	0.705 ± 0.003	Acid volcanics, Kiruna		Welin et al. 1971
34	1590 ± 45	0.708 ± 0.002	Sorsele granite	whole-rock & mineral isochron	Welin et al. 1977
35	1590 ± 35	0.712 ± 0.002	Guorbavare granite, Skellefte		Welin et al. 1977
36	1530 ± 25	0.710 ± 0.002	Sjaunjatuottar syenite		Gulson 1972
37	1530 ± 35	0.712 ± 0.003	Lina granite, E. Norrbotten		Welin et al. 1971
38	1503 ± 30	0.713 ± 0.004	Perthite granite, Masugnsbyn		Gulson 1972

[1]Initial $^{87}Sr/^{86}$ ratio [2]All ages based on λ (^{87}Rb) = $1.42 \cdot 10^{-11} a^{-1}$ [3]Lofoten-Vesterålen

mantle, the lower continental crust and the upper continental crust. However, the average Rb/Sr ratios of these zones place constraints on the range of initial $^{87}Sr/^{86}Sr$ ratios that could be expected in rocks deriving their strontium from them (Faure & Powell 1972, pp. 43–54).

The low initial ratios of the mangerite series in Lofoten-Vesterålen (10 of the rock suites in Table 3) indicate that they did not originate by extensive anatexis of basement rocks in the area. It has been suggested that they have been derived by magmatic differentiation from a basic mass emplaced in the lower crust, with limited contamination by crustal material in some cases (Griffin et al. 1978).

The remaining 3, granitic suites from Lofoten-

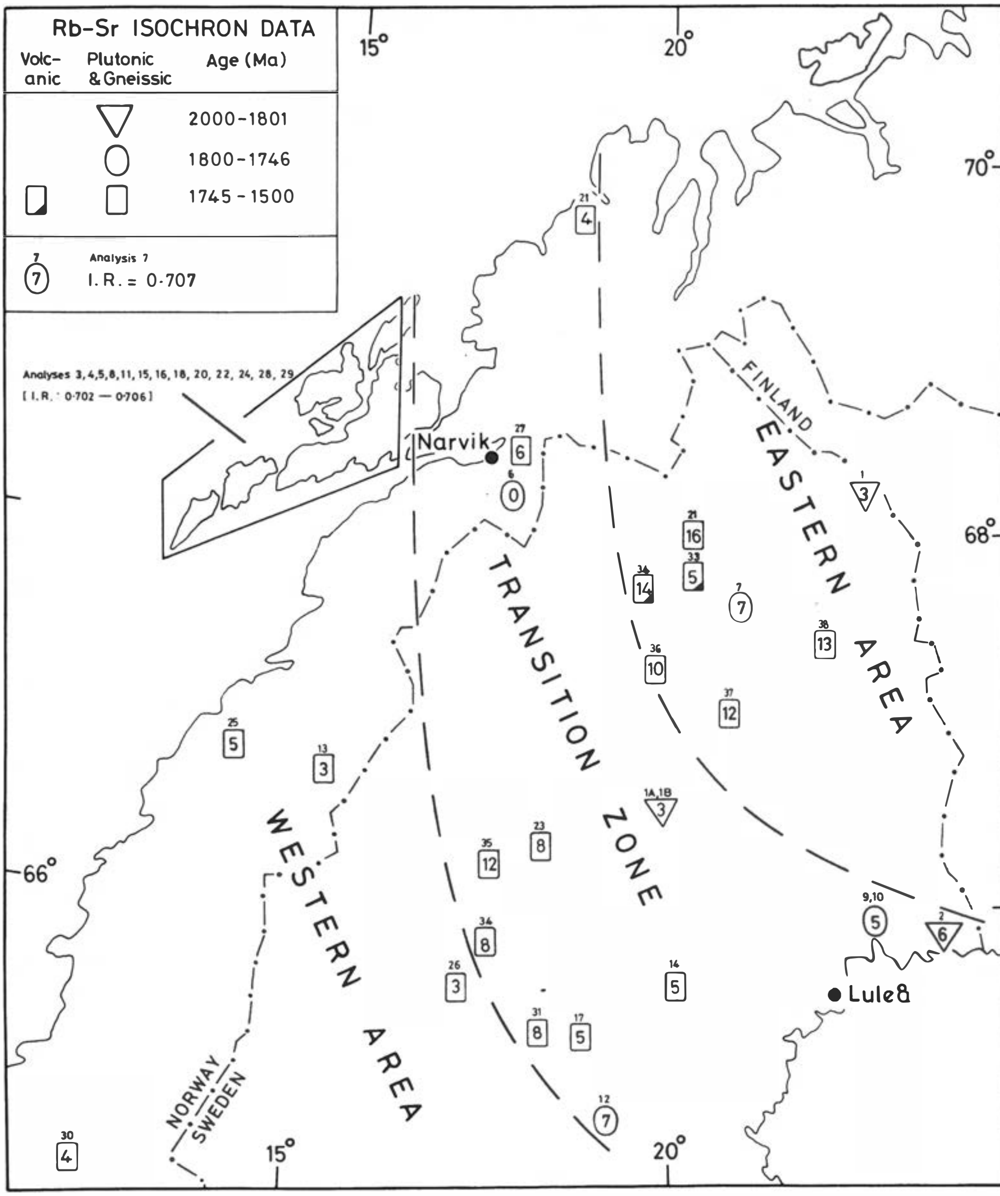

Fig. 6. Distribution of initial $^{87}Sr/^{86}Sr$ ratios (I.R.) listed in Table 3.

Vesterålen (Table 3) have initial ratios comparable to the mangerites, and cannot have originated by extensive crustal anatexis either.

Four rock suites from the western area outside Lofoten-Vesterålen are included in Table 3. All are dominantly granitic. The significance of the Rb-Sr data from the Sjangeli-Rombak window has been discussed above. The remaining 3 suites include gneissic rocks which may have been affected by Caledonian metamorphism (Wilson & Nicholson 1973). Although the origin of these gneisses is not definitely established, it has been suggested that those at Nasafjäll may have had a simple magmatic origin (Wilson & Nicholson 1973, Discussion). Whether they were derived from magmatic or sedimentary rocks (Steenken

1957) the parent material, like that of the granitic rocks in the Sjangeli-Rombak window and Lofoten-Vesterålen, cannot have had an extensive previous crustal history.

All the rocks suites in the eastern area are acidic. The relatively wide range of initial ratios can be interpreted in terms of two types of derivation: (1) From an isotopically heterogeneous collection of parent materials, (2) From two or more isotopically homogeneous sources (e.g. crustal rocks of similar age and Rb/Sr ratio, and mantle-derived magma). The available data do not allow the relative merits of these alternatives to be assessed. However, if material derived from isotopically normal mantle is involved, it must have been contaminated by significant proportions of crustal material in the majority of rock suites. The volcanic rocks from Duobblon and Kiruna (Welin et al. 1971) and the granites from Adak and Arvidsjaur (Welin et al. 1977) could be derived from substantially uncontaminated mantle material.

Except in Lofoten-Vesterålen few rocks older than 2000 Ma have been dated in northern Scandinavia west of Finland. Thus the nature of the crust into which the Svecofennian intrusives were emplaced is largely unknown, although experimental work suggests that the granites may have been emplaced at depths less than 35 km (Hietanen 1975).

The rock suites in Table 3 show a general increase in initial ratio with decreasing radiometric age (Fig. 7). This suggests a change with time either in the isotopic composition of the source regions or in the relative proportions of material contributed by more than one source (Derivation 2, above). An expansion of the source regions to higher levels (Hietanen 1975) could account for this, provided that the crust was isotopically stratified.

Tectonic implications

Mainland Scandinavia. – Lundqvist (1979) has discussed the Proterozoic evolution of Sweden in terms of plate tectonic models of the Svecofennian period proposed by several authors, including Hietanen (1975) and Rickard (1978). The models incorporate an island arc system with a NW-SE trending subduction zone dipping northeastward beneath the pre-Karelian continental block. In such a system the average age of crustal material in the island arc would be younger than that further east, where the ratio of recent volcanogenic material to ancient crust would be lower. So the pattern of initial $^{87}Sr/^{86}Sr$ ratios shown by the granitic rock suites from *mainland* Scandinavia in Table 3, including those west of the Caledonian front, is compatible with formation in a post-2000 Ma subduction system.

Addition of volcanic and sedimentary material to the top of the crust in the island arc would tend to cause upward migration of isotherms. The consequent upward movement of the zone of anatexis could have caused incorporation in the resulting Svecofennian granites of material with high $^{87}Sr/^{86}Sr$ ratios from upper levels. This would be consistent with the observed increase in initial ratios of the granite with time.

Lofoten-Vesterålen and western Troms. – The magmatic and metamorphic history of Lofoten-Vesterålen during the period 2100-1700 Ma is well documented (Griffin et al. 1978). The pre-Caledonian spatial relationship between the Lofoten-Vesterålen and western Troms areas and the Baltic shield is debatable, and the amount of Caledonian crustal shortening between them is not known. However, if the three areas formed part of the same pre-Caledonian plate, the contrast between the low Svecofennian initial ratios west of the Caledonian front and the higher ratios further east is compatible with a north-eastward dipping subduction system and lends support to the models discussed by Lundqvist. Alternatively, the post-1800 Ma mangerites of Lofoten-Vesterålen may be derived from a different, tensional, tectonic environment (Griffin et al. 1978).

Conclusions

1. Granitic rocks of Svecofennian age are present in the Sjangeli-Rombak window, and were largely unaffected isotopically by Caledonian events.
2. An eastward increase in the initial $^{87}Sr/^{86}Sr$ ratios of Svecofennian igneous and gneissic rocks in northern Scandinavia may reflect an E-W variation in parent rock type.
3. This contrast is compatible with plate tectonic models incorporating a subduction zone dipping eastwards beneath the pre-Karelian continental block.
4. Intrusive rocks formed in Lofoten-Vesterålen during the Svecofennian period have initial $^{87}Sr/^{86}Sr$ ratios compatible with this model,

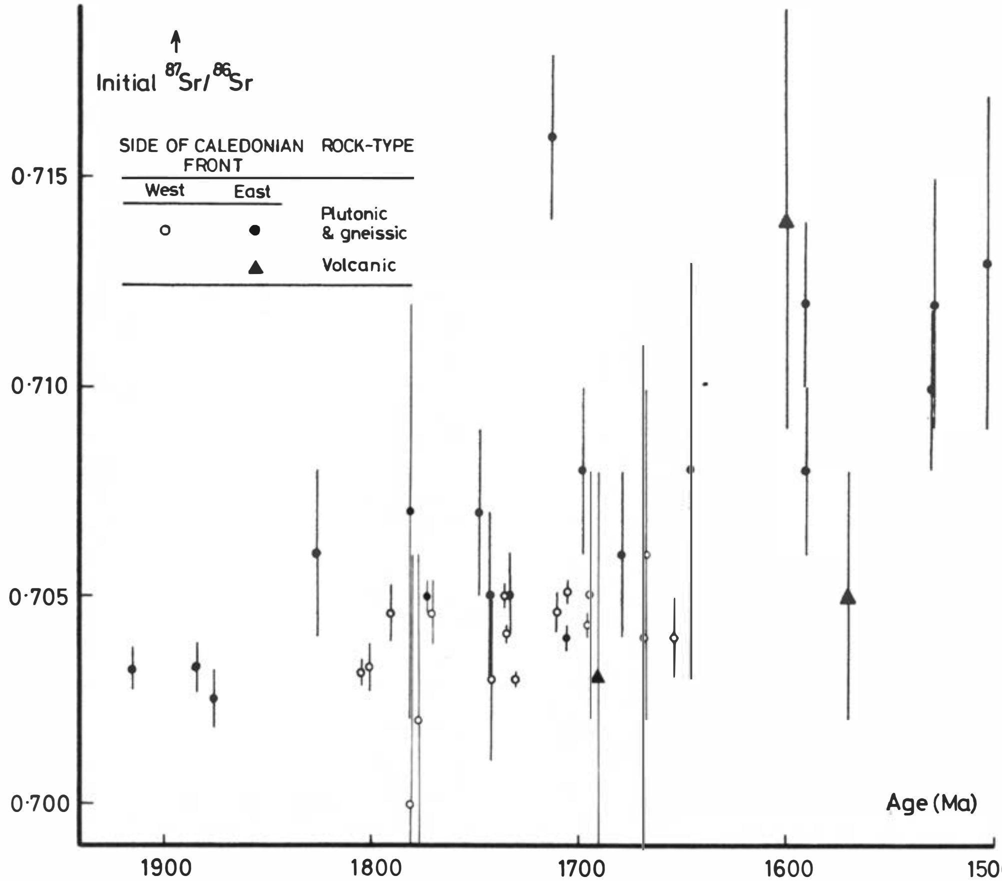

Fig. 7. Relationship between ages and initial $^{87}Sr/^{86}Sr$ ratios for isochron data listed in Table 3. Bars indicate quoted errors.

but petrological considerations may indicate that they originated in a different environment.

5. The supracrustal series in the Sjangeli-Rombak window is older than 1780 Ma.

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References

Åberg, G. 1978: Precambrian geochronology of south-eastern Sweden. *Geol. Fören. Stockholm Förh. 100,* 125–154.

Adamek, P. M. 1975: Geology and mineralogy of the Kopparåsen uraninitesulphide mineralization, Norrbotten County, Sweden, *Sver. geol. unders. C. 712,* 69 pp.

Adamek, P. M. & Wilson, M. R. 1979: The evolution of a uranium province in northern Sweden. *Phil. Trans. R. Soc. London. A 291,* 355–368.

Andersen, A. 1980: The age of the Precambrian basement in western Troms, Norway. *Geol. Fören. Stockholm Förh. 101,* 291–298.

Birkeland, T. 1976: Skjomen, Berggrunnsgeologisk kart 1:100.000, Sheet N 10, *Nor. geol. unders.*

Brueckner, H. K. 1971: The age of the Torset Granite, Langøy, northern Norway. *Nor. Geol. Tidsskr. 51,* 85–87.

Faure, G. & Powell, J. L. 1972: *Strontium Isotope Geology,* Springer-Verlag, New York, 188 pp.

Griffin, W. L., Taylor, P. N., Hakkinen, J. W., Heier, K. S., Iden, I. K., Krogh, E. J., Malm, O., Olsen, K. I., Ormaasen, D. E. & Tveten, E. 1978: Archaean and Proterozoic crustal evolution in Lofoten-Vesterålen, N. Norway. *J. Geol. Soc. Lond. 135,* 629–647.

Gulson, B. L. 1972: The Precambrian geochronology of granitic rocks from northern Sweden. *Geol. Fören. Stockholm Förh. 94,* 229–244.

Gustavson, M. 1966: The Caledonian mountain chain of the southern Troms and Ofoten areas. I: Basement rocks and Caledonian metasediments. *Nor. geol. unders. 239,* 162 pp.

Gustavsson, M. 1969: The Caledonian mountain chain of the southern Troms and Ofoten areas. II: Caledonian rocks of igneous origin. *Nor. geol. unders. 261,* 110 pp.

Gustavson, M. 1972: The Caledonian mountain chain of the southern Troms and Ofoten areas. III: Structures and history. *Nor. geol. unders. 283,* 56 pp.

Heier, K. S. & Compston, W. 1969: Interpretation of Rb-Sr age patterns in high-grade metamorphic rocks, north Norway. *Nor. Geol. Tidsskr. 49,* 257–283.

Hietanen, A. 1975: Generation of potassium-poor magmas in the northern Sierra Nevada and the Svecofennian of Finland. *J. Res. U. S. Geol. Surv. 3,* 631–645.

Kulling, O. 1964: Översikt över norra Norrbottensfjällens kalendonberggrund. *Sver. geol. unders. Ba 19,* 166 pp.

Lundqvist, T. 1979: The Precambrian of Sweden. *Sver. geol. unders. C. 768,* 87 pp.

Råheim, A., Gale, G. H. & Roberts, D. 1979: Rb, Sr ages of basement gneisses and supracrustal rocks of the Grong area, Nord-Trøndelag, Norway. *Nor. geol. unders. 354,* 131–142.

Reymer, A. P. S. 1979: Age determinations on reworked crystalline basement of the Grong culmination, Norway. *Nor. geol. unders. 354,* 143–149.

Rickard, D. T. 1978: The Svecokarelian anomalous ore lead line. *Geol. Fören. Stockholm Förh. 100,* 19–29.

Skiöld, T. 1976: The interpretation of the Rb-Sr and K-Ar ages of late Precambrian rocks in southwestern Sweden. *Geol. Fören. Stockholm Förh. 98,* 3–29.

Skiöld, T. 1977: Granite ages in the Kalix area, northern Sweden. *Geol. Fören. Stockholm Förh. 99,* 76–79.

Skiöld, T. 1979: U-Pb and Rb-Sr whole rock and mineral ages of Proterozoic intrusives on map sheet Lannavaara, northeastern Sweden. *Geol. Fören. Stockholm Förh. 101,* 131–137.

Skiöld, T. & Larsson, C. 1978: Age data on Proterozoic granitoids from the Novijaur area of northern Sweden. *Geol. Fören. Stockholm Förh. 100,* 171–176.

Steenken, W. F. 1957: Geology and petrology of the region south of Russånes, Saltdal, Norway. *Meded. Geol. Inst. Univ. Amst. 244.*

Vogt, T. 1941: Trekk av Narvik-Ofoten traktens geologi. *Nor. Geol. Tidsskr. 21,* 198–213.

Vogt, T. 1950: Narvik, Berggrunnsgeologisk kart, 1:100.000. *Nor. geol. unders.*

Welin, E. 1970: Den Svecofenniska orogena zonen i norra Sverige – en preliminär diskussion. *Geol. Fören. Stockholm Förh. 92,* 433–451.

Welin, E., Christiansson, K. & Nilsson, Ö. 1970: Rb-Sr age dating of intrusive rocks of the Haparanda suite. *Geol. Fören. Stockholm Förh. 92,* 336–346.

Welin, E., Christiansson, K. & Nilsson, Ö. 1971: Rb-Sr radiometric ages of extrusive and intrusive rocks in northern Sweden. I. *Sver. geol. unders. C. 666,* 31 pp.

Welin, E., Einarsson, O., Gustafsson, B., Lindberg, R., Christiansson, K., Johansson, G. & Nilsson, Ö. 1977: Radiometric ages of intrusive rocks in northern Sweden. II. *Sver. geol. unders. C. 731,* 21 pp.

Wilson, M. R. 1980: Granite types in Sweden. *Geol. Fören. Stockholm Förh. 102,* 167–176.

Wilson, M. R. & Nicholson, R. 1973: The structural setting and geochronology of basal granitic gneisses in the Caledonides of part of Nordland, Norway. *J. Geol. Soc. Lond. 129,* 365–387.

Wilson, M. R. & Sundin, N. O. 1979: Isotopic age determinations on rocks and minerals from Sweden 1960–1978. *Sver. geol. unders., Rapp. o. medd. 16,* 42 pp.

York, D. 1969: Least squares fitting of a straight line with correlated errors. *Earth Planet. Sci. Lett. 5,* 320–324.