K–Ar age determinations on the Raipas suite in the Komagfjord Window, northern Norway

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K-Ar data are presented for the age of the metamorphism of the pre-Caledonian basement rocks which are exposed in a large tectonic window within the Caledonide orogen of West Finnmark. Metamorphic hornblendes separated from metabasites of the Raipas suite in the Komagfjord Tectonic Window yield concordant radiometric ages which date the peak of regional metamorphism at about 1840 M.a., thus confirming the suggestion that this suite is of Svecokarelian age. The metabasites are considered to represent the northward continuation, beneath the Caledonian nappe pile, of greenstone supracrustal belts which developed in N. Finland, N. Sweden and the Finnmarksvidda of N. Norway during the Early Proterozoic. These Svecokarelian greenstones are distinctly different in age and lithology from the greenstone belts of E. Finland.

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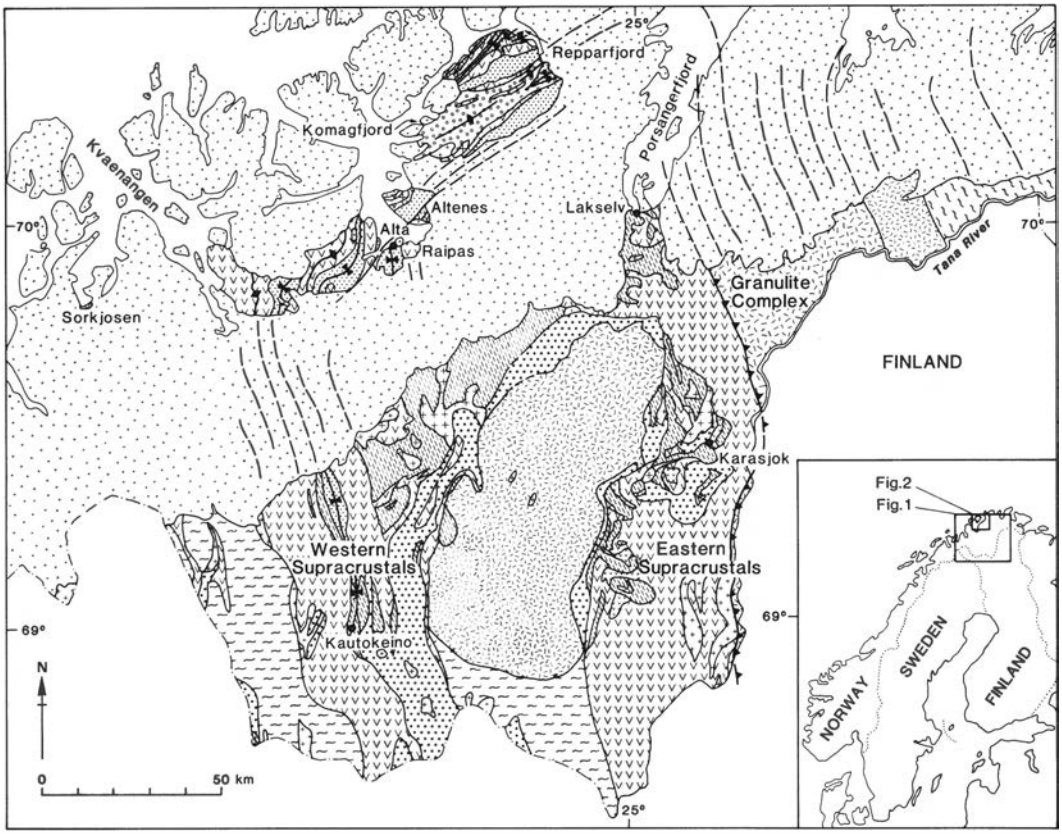
The Komagfjord Tectonic Window (Reitan 1963) forms a large (c 900 km^2) basement culmination within the Caledonian Kalak Nappe Complex (Roberts 1974) of West Finnmark (Fig. 1). In the Alta-Kvænangen Window, which represents the continuation of the basement culmination along the Caledonian strike to the southwest, similar lithologies, mostly basaltic lavas, tuffs and sediments at low metamorphic grade occur (Gautier 1977). These basement rocks have long been considered Precambrian for they are unconformably overlain by a little-deformed Vendian sedimentary sequence, which locally includes the Varanger tillite at its base. Since the initiation of detailed geological investigation in Finnmark, the basement rocks have been referred to as the Raipas system (Dahll, *in* Reusch et al. 1891) or Raipas suite (Reitan 1963). On a purely lithological basis, various authors (e.g. Holtedahl 1918, 1960, Holmsen et al. 1957, Reitan 1963, Jansen 1976) have correlated them with the Karelian supracrustal rocks of the Finnmarksvidda, N. Finland and N. Sweden.

Gautier et al. (1979) have recently reported K-Ar age determinations for metabasaltic rocks of the Raipas suite from the Alta-Kvænangen Window. Pillow lavas, tuffs and dolerites metamorphosed under lower greenschist conditions yielded highly variable whole-rock K-Ar ages. The majority of samples yielded ages less than 1550 M.a., though three samples gave rather older ages (KA-748, 1947 ± 71 M.a.; KA-749, 1990 ± 71 M.a.; KA-579, 2509 ± 128 M.a.). Gautier et al. (1979) concluded from these data that the Raipas suite had a minimum age of 1400–1500 M.a. and was probably as old as 1800–2000 M.a. In E. Finnmark, the Petsamo Group has yielded Rb-Sr isochron ages of 1760 M.a. for a greenstone and 1800 M.a. for a quartz keratophyre (A. Råheim, pers. comm. 1982).

In Finland, the Svecokarelian orogeny was dated at around 1800 M.a. by Kouvo (1958). The Svecokarelian supracrustal rocks at Sivakkavaara have been studied by van Breemen and Bowes (1977). Muscovite books from a pegmatite, emplaced between the third and fourth deformational phases of the Svecokarelian orogeny, indicated a minimum Rb-Sr age of 1820 M.a. Loss of radiogenic Sr continued until at least 1700 M.a., which suggested to the authors that elevated regional temperatures had been maintained for at least 120 million years after emplacement.

Although the Karelian greenstones (e.g. the Kiruna greenstones) have not been dated directly in northern Sweden, a variety of radiometric measurements (mainly by Welin and his co-workers) has provided some indirect evidence bearing on their age. The Kiruna Porphyries, a suite of



Caledonian cover

Tanafjord, Vestertana Groups and equivalents: Gaissa, Laksefjord Nappes and Kalak Nappe Complex.
Aeromagnetic anomalies (schematic) indicate basement trends beneath the Caledonian cover

Proterozoic basement

Karelian of Finnmark Windows
- Metasandstones
- Pelitic, carbonate metasediments
- Basic metavolcanics, some metasediments
- Immature clastics, conglomerates, some lavas, tuffs etc.

Plutonic intrusions
- Gabbro, peridotite etc.
- Granite, trondhjemite etc.

Karelian Supracrustals of Finnmarksvidda
- Metasandstones
- Pelitic, carbonate metasediments
- Picritic metavolcanics
- Basic metavolcanics, some metasediments
- Quartzite/Conglomerate
- Quartz-feldspar gneiss

Pre-Karelian Basal Gneiss Complex
- Granitic gneiss

Early Proterozoic Lapland Granulite Complex
- Quartz-feldspar gneiss
- Granodioritic gneiss, migmatite
- Granulite
- Thrust
- Major Svecokarelian anticline/syncline

Fig. 1. Precambrian basement of Finnmark. Data from 1:1 m. Geological Map of Norway; 1:250,000 Geological Sheets Hammerfest, Karasjok and Enontekiö (Provisional); 1:250,000 Aeromagnetic Sheets Hammerfest, Nordreisa and Kistrand; Holmsen et al. (1957); Crowder (1959); Bugge (*in* Holtedahl 1960); Wennervirta (1969): Gautier et al. (1979).

intermediate and acid volcanic rocks which unconformably overlie the Kiruna greenstones (Offerberg 1967), have been dated by the Rb-Sr method at 1570 ± 65 M.a.* ($\lambda = 1.42 \times 10^{-11} y^{-1}$). All ages have been (re-)calculated with decay constants and abundances recommended by IUGS (Steiger & Jäger 1977). The acid volcanics of the Kaska Tjaurek area, which are lithologically similar, yielded an age of 1600 ± 90 M.a. and are probably contemporaneous (Welin et al. 1971).

In addition, the Karelian greenstones are in-

truded by the synorogenic differentiated Haparanda suite of gabbroic, dioritic and granodioritic rocks (Ödman 1957). Welin et al. (1970) obtained a Rb-Sr whole-rock and mineral isochron for the intrusive suite, dating it at 1825 ± 40 M. a.

In the Northern Baltic Shield, the Karelian supracrustal belts are underlain by a sialic continental crust which has grown during a succession of accretionary episodes from Archaean to Early Proterozoic time (Read & Watson 1975). Pre-existing basement has not yet been recognised underlying the Svecofennian schists and gneisses of central and southern Finland and Sweden which have generally been regarded as contemporaneous with the Karelian schists (Metzger 1959, Simonen 1960). The contrasting Karelian supracrustals (which include basaltic lavas, quartzites and dolomites deposited on pre-existing continental basement) and Svecofennian 'eugeosynclinal' facies (of basic to acid volcanics, tuffs and greywackes without recognisable basement) have been interpreted in terms of global tectonic models by various authors, notably Hietanen (1975).

For the 'granite-gneiss complex' underlying the Svecokarelian greenstone belts, considerably more radiometric data are available than for the supracrustals themselves. The oldest rocks in the Baltic Shield occur in the Kola Peninsula, where radiometric dating by a variety of methods suggests ages as great as 3600 M.a. (Gerling et al. 1968). Amphibolite facies migmatites in Vesterålen, Norway, have model ages of 2600 M.a. on the basis of their Sm-Nd, Rb-Sr and Pb-Pb total rock systematics (Jacobsen & Wasserburg 1978). Merilainen (1976) has obtained a Pb-Pb age of 2865 M.a. for the granite-gneiss complex of N. Finland and a U-Pb age of 2730 M.a. for the granite-gneiss complex of Skoganvarre in N. Norway. A comparable U-Pb age for zircon of 2834 ± 40 M.a. has recently been obtained from the granite-gneiss complex in the Laanavaara district of northern Sweden by Skiöld (1979).

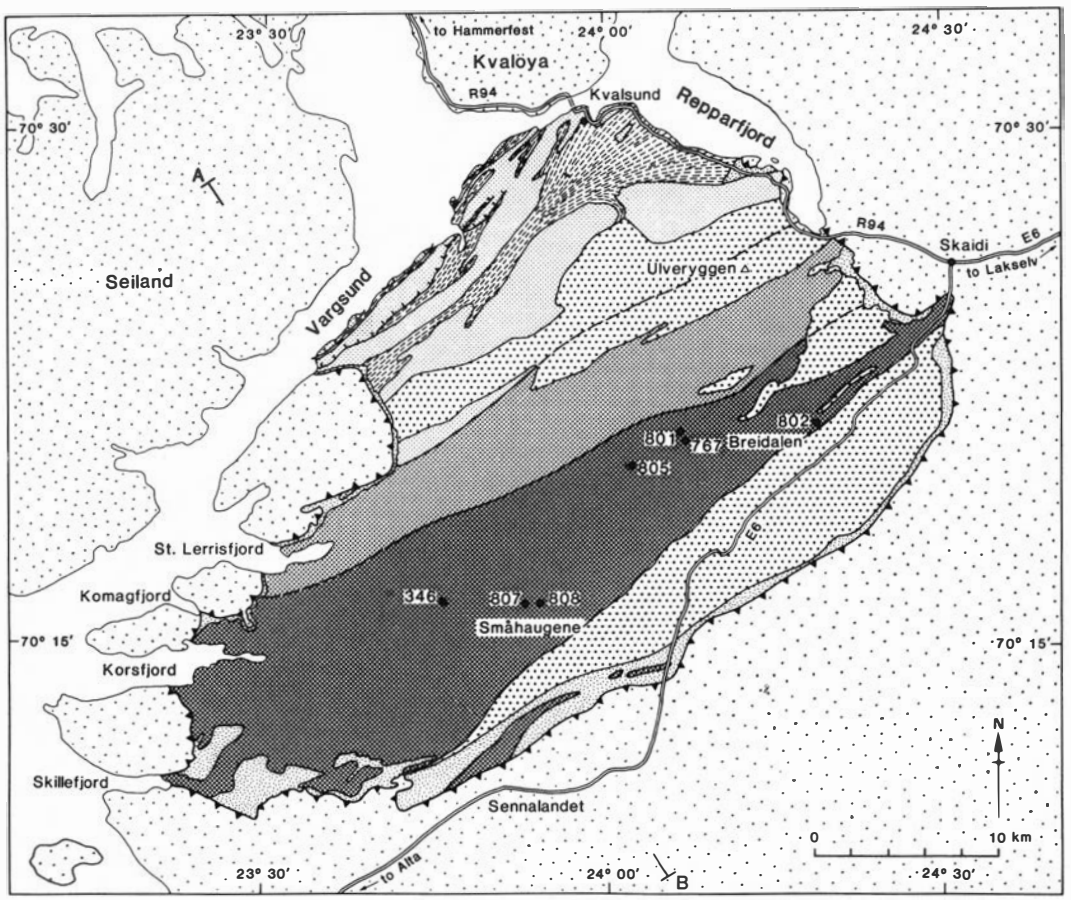
In E. Finnmark, the Lapland Granulite Complex appears to have undergone granulite facies metamorphism during the Archaean, followed by reactivation during the Early Proterozoic (A. Råheim, pers. comm. 1982). Retrograde, upper amphibolite facies metamorphism of this complex occurred at about 1900 M.a. (Merilainen 1976). These basement complexes all contain domains which yield younger radiometric ages considered to reflect reworking during the Svecokarelian.

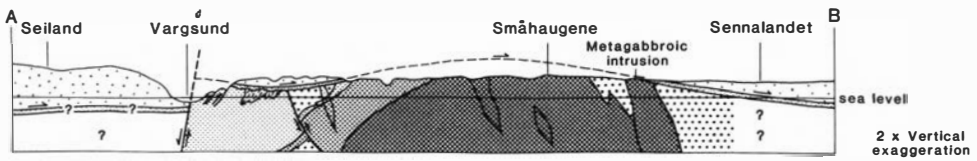
Most workers have traditionally regarded the greenstone belts of East Finland as Svecokarelian and similar to those of the Kiruna area in N. Sweden and the Finnmarksvidda of N. Norway. However, recent work, summarised by Gaàl et al. (1978), has revealed that this assumption is not necessarily correct. Some of these greenstones may in fact be Archaean, as zircons yielding U-Pb ages of 2800 M.a. have been found in granodiorites which crosscut the Ilomantsi and Suomussalmi-Kuhmo greenstone belts. The presence of komatiitic lavas in the Kittila belt of N. Finland was first suggested by Mutanen (1976), and these have been identified in the Suomussalmi-Kuhmo belt by Blais et al. (1977). It has also been suggested that the West Inari schist zone which continues into the Karasjok area of Norway is of pre-Karelian age (Merilainen 1976).

Further detailed investigations may well show that other belts of supracrustal rocks are also of Archaean age, and, although many of the greenstone supracrustal sequences in the Northern Baltic Shield have previously been assigned to the Proterozoic, their age is presently uncertain. This study was therefore undertaken to determine the age of the Raipas suite in West Finnmark and its relationship to the various elements of the Baltic Shield outlined above.

Sampling procedure

Several samples of basic igneous rocks which have been regionally metamorphosed at epidote-amphibolite grade were collected from sites in the SE part of the Komagfjord Tectonic Window (Fig. 2). The samples obtained were amphibolitic metabasalts of the Holmvann Group (Pharaoh 1980) or amphibolitic metagabbros intruded into latter. The Holmvann Group forms the lowest stratigraphic unit of the Raipas suite in the Komagfjord Window. It is overlain by quartzofeldspathic metasediments of the Saltvann Group, metabasalts of the Nusseren Group and schistose metasediments of the Porsa Group (Pharaoh 1980). Petrographic and structural studies (Jansen 1976) have demonstrated that metamorphism of these higher units of the Raipas suite was coincident with that of the underlying Holmvann Group. The metagabbros form part of a differentiated peridotite-norite-gabbro suite emplaced during the same metamorphism (Reitan 1963) and referred to as the Rödfjell Series (Pharaoh 1980). Around the margin of the window, this supracrustal suite is unconformably overlain (Fig. 2) by a thin sequence of sediments





Caledonian cover

Autochthonous sediments of Vendian age

Kalak Nappe Complex

Proterozoic Basement

Zone	Facies		
Chlorite	Greenschist	Svecokarelian prograde (M_1k) metamorphic zonation in metabasites of the Holmvann and Nusseren Groups and Rödfjell Series	Porsa Group; Saltvann Group and equivalents (Karelian metasediments)
Biotite			
Hornblende	Epidote–Amphibolite		

Caledonian shearing

Fig. 2. Svecokarelian prograde (M_1k) metamorphic zonation in metabasites of the Holmvann and Nusseren Groups. The location of hornblende-bearing samples used for radiometric analysis is also shown.

which are of probable Vendian age (Jansen 1976, Pharaoh 1980).

The sample types and locations were chosen to maximise the probability of obtaining meaningful ages. The blue-green hornblende, ubiquitously developed in the metabasites at this metamorphic grade, has the highest retentivity for argon-40 of any mineral or whole-rock system at greenschist grade. Furthermore the south-eastern area is relatively unaffected by Caledonian deformation, the NW part of the window having suffered considerable cataclastic deformation during the Finnmarkian stage in early Ordovician times (Sturt et al. 1975). The possibility of Caledonian disturbances to the isotopic systems was therefore reduced by sampling the hornblende-bearing rocks in the south-east.

Analytical procedure

Rock samples were crushed, sieved and the hornblendes separated by conventional magnetic and heavy liquid techniques. Potassium concentrations were determined flame photometrically, using a sodium buffer and lithium internal standard. Argon-40 contents were measured statically with an MS10 mass-spectrometer. The ages calculated for the hornblendes are presented in Table 1.

Table 1. K-Ar analytical data and radiometric ages for the Raipas suite in the Komagfjord Tectonic Window.

Sample No.	K (wt.%)	Radiogenic ^{40}Ar (%)	Radiogenic ^{40}Ar ($x10^{-4}$scc/g)	Age (Ma)
1. 801	1.17	98.64	1.453	1840 ± 37
		99.41	1.443	1832 ± 36
807	.402	98.70	.5091	1861 ± 37
		98.35	.5060	1854 ± 37
		98.34	.5018	1844 ± 37
346	.339	97.55	.4304	1864 ± 37
		98.31	.4193	1833 ± 37
		97.66	.4117	1812 ± 36
2. 802	.324	96.58	.3919	1810 ± 36
3. 767	.901	98.92	1.129	1848 ± 37
		99.47	1.131	1851 ± 37
808	.520	98.68	.6273	1806 ± 37
		98.44	.6536	1853 ± 37
		98.97	.6817	1902 ± 38
805	.598	98.76	.9205	2096 ± 42
		98.17	.9205	2096 ± 42
		98.69	.9122	2085 ± 41

$\lambda\beta = 4.962 \times 10^{-10}yr^{-1}$; $\lambda_k = 0.581 \times 10^{-10}yr^{-1}$; $^{40}K = 0.01167$ atom%

Mean of mean ages = 1840 Ma

Results

On the basis of their petrography and field relationships the samples can be divided into three groups, as follows:

1. *Amphibolitic metabasalts* (Table 1, Nos. 801, 807, 346). These amphiboles are fresh green-blue hornblendes which recrystallised from the primary igneous mineralogy during the peak of metamorphism (M_1k), soon after the end of the first fold phase (F_1k). Sample 801 is from a hornblendite pebble in the 'Greenstone Conglomerate' first described by Holtedahl (1918), while 807 and 346 are from metabasaltic lavas. The measured ages lie in the range 1812 to 1864 M.a. and the mean age is 1842 M.a.

2. *Amphibolitic metabasalt* (Table 1, No. 802). This sample is representative of a group which differs from the preceding in that petrographical examination indicates that the amphiboles crystallised in the S_1k schistosity but were later affected by a second phase of deformation (D_2k) which produced considerable cleavage crenulation. These amphiboles tend to be paler and less pleochroic than those in the first group. The sample analysed yields an age of 1810 ± 36 M.a. (Table 1).

3. *Amphibolitic metagabbros* (Table 1, Nos. 767, 808, 805). These blue-green hornblendes were obtained from synorogenic gabbros which were intruded just prior to M_1k and metamorphosed by this event. The calculated ages range from 1806 to 2096 M.a.

Interpretation

All the hornblendes in the first group yield ages about 1840 M.a. which are concordant within their analytical uncertainties. The wide range in potassium content in the samples suggests that this age is significant, and it is interpreted as the date at which the hornblendes passed through their blocking temperatures (c. 500°C) following the peak of metamorphism (M_1k). Sample 801 (from the pebble) appears to have been completely degassed during the metamorphism, as it contains no measurable inherited argon-40. Sample 802 gives a slightly younger age (1810 ± 36

M.a.), perhaps reflecting retrograde metamorphism during the second phase of Precambrian deformation.

From the field evidence, Reitan (1963) considered that the synorogenic metagabbroic suite had clearly been metamorphosed at the same time as the host metabasalts, and this has been confirmed by the field and petrographical observations of one of us (T. C. P.). The ages measured for samples 767 and 808 substantiate this conclusion, as their mean age is 1852 M.a. The ages calculated for sample 805 seem systematically higher, and have a mean of 2093 M.a. However, it is considered unlikely that this is indicative of an extended pre-metamorphic history but rather results from the incorporation of extraneous argon-40 at the time of the metamorphism. Hebeda et al. (1973) have reported on a gabbroic body in which a hornblende contains excess argon-40 in a concentration of about 2.5×10^{-5} sccs/gm. which was apparently introduced during a tectonothermal event. The presence of a comparable concentration in sample 805 would appear to be the simplest explanation for the observed age difference.

Conclusions

It is clear from our results that the Raipas suite in the Komagfjord Tectonic Window has been involved in the Svecokarelian orogeny and that the peak of regional metamorphism in this area occurred around 1840 M.a. There is no evidence for disturbance of the hornblende isotopic systems when the Caledonian nappes were thrust across the window a distance of at least 85 km during the Finnmarkian stage (Sturt et al. 1975). The NW part of the window appears to have acted as a buffer zone, against which much of the Caledonian stress was expended. Rb-Sr ages from this district of about 850 M.a. (I. R. Pringle, pers. comm.) are almost certainly indicative of Caledonian reworking of Precambrian metasediments.

As the metabasalts and metasediments of the Alta-Kvænangen and Komagfjord Tectonic Windows are so similar lithologically, we believe that those of the former also experienced Svecokarelian metamorphism, and that most of the whole-rock K-Ar ages reported for this area by Gautier et al. (1979) are erroneously low on account of variable argon loss. Geophysical evidence suggests that the greenstones in this area continue beneath a thin cover of Caledonian nappes (Åm 1975) and connect directly (Fig. 1) with the lithologically similar rocks of the Finnmarksvidda described by Holmsen et al. (1957). These, in turn, pass southwards into northern Sweden to link up with the greenstone belts of the Vittangi and Kiruna districts. It therefore seems probable that all of the greenstone belts in the north-west part of the Baltic Shield (stretching from West Finnmark down into northern Sweden) are of Svecokarelian age.

None of these Early-Middle Proterozoic greenstone belts is known to contain komatiitic lavas. In eastern Finland the situation is somewhat different as these have been recognised in some belts. Again here isotopic ages suggestive of an Archaean origin have been reported. Clearly further investigations to distinguish these differing types of greenstone terrain in the Baltic Shield will be of fundamental importance for the future.

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