Rb-Sr and K-Ar Caledonian ages from the Upper Eleonore Bay Group and Cambrian metasediments of the East Greenland Caledonian fold belt

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Abstract

Fine sediment fractions < 2 μ extracted from various formations of Upper Proterozoic and Cambrian age in Canning Land and Segelsällskapet Fjord in East Greenland are anchimetamorphic to strongly diagenetic. Rb-Sr and K-Ar isotopic analyses indicate that the metamorphic and diagenetic changes correspond to the main Caledonian event at *c.* 450 Ma while some of the data are consistent with a younger event at nearly 400 Ma, possibly connected to late Caledonian tectonics. The study also shows the peculiar features of the isotopic diagrams often observed in such conditions: parallel isotopic lines, discordant behaviour of the Rb-Sr and K-Ar chronometers, and the necessity of collecting sets of samples from small homogeneous areas.

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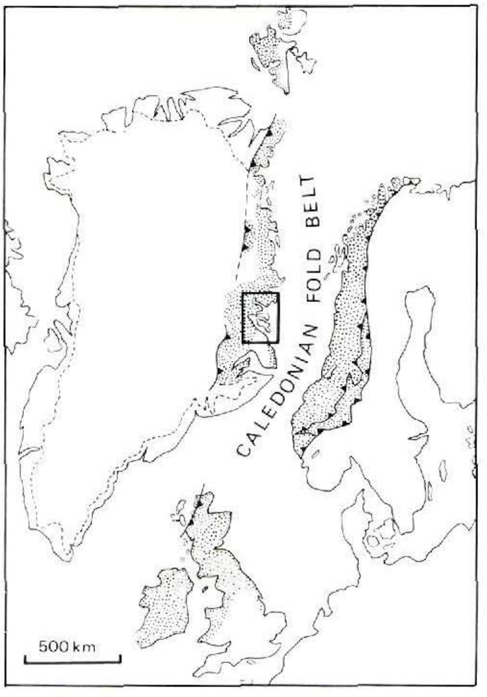
Introduction

A number of methods have been employed on the geochronology of the metamorphic and intrusive rocks from the Caledonian fold belt of East Greenland which have permitted dating of the Caledonian thermo-tectonic episode with some precision (Hansen & Steiger, 1971; Oberli & Steiger, 1973; Hansen *et al.*, 1978). Many results point to the presence of several pre-Caledonian provinces within the central metamorphic complex and reveal its poly-orogenic nature (Steiger *et al.*, 1979; Higgins *et al.*, 1978, 1981; Rex & Gledhill, 1981).

The purpose of the present study was to analyse slightly metamorphosed sediments of known age using Rb-Sr and K-Ar methods. Because of the very low metamorphic grade of many parts of the Caledonian suprastructure (Wegmann, 1935) it was thought these methods would give either depositional or diagenetic pre-Caledonian ages. In fact, all ages obtained point to a nearly complete isotopic redistribution of isotopes during the Caledonian orogeny, and confirm the data obtained from the infrastructure.



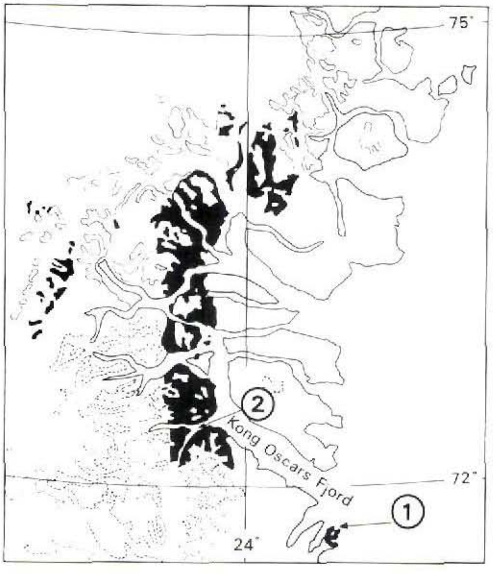


Fig. 1. Outcrops of the Eleonore Bay Group (in black) in the East Greenland Caledonides. 1. Canning Land area. 2. Segelsällskapet Fjord and Alpefjord. Inset: Location of the investigated area in the Caledonian fold belt in a pre-drift configuration (after Henriksen & Higgins, 1976).

Geological setting

The general distribution of the Upper Eleonore Bay Group and the Lower Palaeozoic succession in East Greenland has been known for many years and parts of this sequence have been reinvestigated by one of us (Caby, 1972; 1976a) in Canning Land and in the Alpefjord region (fig. 1). The succession observed in both areas is nearly identical. The Upper Eleonore Bay Group, which rests conformably upon up to 8000 m of the Lower Eleonore Bay Group (mainly dark shales and quartzites) is exposed in many parts of the fold belt between 71° and 74°N. It consists of the Quartzite Series below, followed by the Multicoloured Series (various shales and siltstones with intercalations of carbonates), with the Limestone-Dolomite Series at the top.

The Quartzite Series (~ 2000 m) is a succession of well sorted sandstones, quartzites, silty shales and shales in which cross-bedding, ripple marks, mud-cracks, grading and rhythmic bedding indicate shallow water sedimentation (Haller, 1970; Henriksen & Higgins, 1976).

In the Multicoloured Series, mud-cracks, frequently observed in red and green shales of the basal part, suggest a continental environment for the deposition of most of the shales (Caby, 1976a). A progressive passage upwards to dolomitic, varved silty shales and yellow dolomites seems to indicate the initiation of very shallow marine facies with black limestones rich in organic matter and hydrogen sulphide (bed groups 9 and 10). These black limestones with varve-like structures appear to represent carbonate muds fixed by horizontal algal mats, repeatedly exposed and affected by deep polygonal dessication cracks. The cross-bedded fluviatile quartzites of bed group 13, with associated black shales, are reminiscent of the Lower Eleonore Bay Group facies.

In the Limestone-Dolomite Series (bed groups 14 to 19) the clay component is very low. Several beds contain numerous stromatolitic biostromes and spherical oncolite-bearing layers. These facies have been interpreted as deposited in a moderately agitated marine environment, with frequent periods of sub-aerial exposure (Bertrand-Sarfati & Caby, 1976), with possible alternation of deeper water conditions represented by deposition of reworked stromatolites, redeposited oncolite and carbonate muds. A special evolution of some carbonate-rich beds is seen in the extensive total secondary dolomitisation of some originally black limestones (bed group 12) which have been converted into a coarse-grained, pale cream, secondary dolomite rich in hydrogen sulphide. The uppermost dolomitic layers (bed groups 18 and 19) contain cherts, bituminous dolomites with slump structures, and layers of black siliceous shales which could represent deeper water deposits. The stromatolitic association investigated in the Canning Land area points to a late Riphean or Vendian age (Bertrand-Sarfati & Caby, 1976).

There is no visible break in sedimentation between the late Precambrian beds of the Eleonore Bay Group and the overlying Eocambrian (Varangian) Tillite Group, which has been interpreted as a marine glacial formation. However, studies of acritarchs indicate a late Riphean age for the Upper Eleonore Bay Group and a Varangian age for the Tillite Group. According to these investigations there is a hiatus between these two groups (Vidal, 1976).

Tectonics

Classically, a sharp 'zone de décollement' is frequently found between the non-metamorphic Caledonian suprastructure and the crystalline infrastructure ('central metamorphic complex'); in the latter polyphase deformation and high grade metamorphism are at least partly of Caledonian age (Wegman, 1935; Haller, 1955, 1958, 1970).

In the Alpefjord area, deformation and metamorphism progressively increase downwards in the lowermost part of the Lower Eleonore Bay Group. The biotite, almandine and sillimanite isogrades have been mapped in this region by one of us (R. C.), and large scale recumbent folds facing east have been recognised (Caby, 1976b). There is a gradual transition from biotite hornfelses into schistose hornfelses and mica schists downwards. Below the inverted limb of the recumbent folds, penetrative deformation is ubiquitous in pelitic schists and gneisses, the foliation of which is defined by two micas and sillimanite. Mobilisation also progressively appears downwards.

It has been argued that mid-Proterozoic ages obtained in these high grade metasediments in Forsblad Fjord refer to a metamorphic event *c.* 1000 Ma old (Rex & Gledhill, 1981). However, we have developed the idea of pre-depositional ages reminiscent of the source area from isotopic studies of zircons (Caby, 1976a, 1980; Peucat *et al.*, 1985).

In both the Canning Land and Forsblads Fjord areas, the Upper Eleonore Bay Group and overlying Lower Palaeozoic rocks are only affected by gentle open folds and numerous normal, often low-angle, faults (Caby, 1976a, b). It has been demonstrated in Canning Land that within the Upper Eleonore Bay Group and the Lower Palaeozoic sequence, the major structures were formed in gliding units during the Caledonian orogeny and are of *tensional type,* whereas a compressive regime was simultaneously operating at depth (Caby, 1976b). In Canning Land, the main deformations possibly occurred during the deposition of an early Devonian flysch-type unit with olistoliths, which underlies the Lower Devonian porphyries bordering the Jameson Land basin (Caby, 1972).

Caledonian granites cut through the Caledonian suprastructure. In Canning Land, the Kap Wardlaw granite-granodiorite intrudes black shales of the Lower Eleonore Bay Group. It is surrounded by a wide zone of high grade hornfelses exhibiting flow folding and mineral assemblages of the andalusite-cordierite zone. Numerous veins of alaskite, micro-granite and pegmatite also surround it. Quartz diorite, lamprophyre dykes and sheets predate the emplacement of the granite. Pelitic rocks have been converted over some tens of centimetres into high grade gneisses containing cordierite, sillimanite, garnet and green spinel close to the contact of some quartz diorite veins (Caby, 1976b), and such metamorphic evolution is comparable to the metamorphic conditions at depth in the infrastructure. Numerous dykes of lamprophyres and porphyries related to the same igneous centre also intrude the Limestone-Dolomite Series and are considered to represent higher level intrusions which may predate emplacement of the Kap Wardlaw granite.

In the Alpefjord area intrusive two mica granites also cut the Lower Eleonore Bay Group. On both sides of the fjord a major body, the Forsblad Fjord Granite, has a lens-like geometry and appears to be rootless. It is this granite from which a Rb-Sr whole rock isochron of 445 ± 5 Ma has been obtained (Rex *et al.,* 1976). In its upper and lateral aureole, flattened spots (muscovite, possible pseudomorphs after andalusite) in the outer zone, and euhedral poikiloblasts of biotite, staurolite and garnet cross-cutting the cleavage in unfolded beds of the inner zone point to a syn- to late kinematic emplacement of this granite.

Numerous sub-vertical normal faults and strike-slip faults of younger age (post-Devonian, possibly Tertiary) cut both areas. Basaltic dykes of Tertiary age have also been emplaced in the Canning Land area.

Sampling, petrography and mineralogy of the investigated samples

Samples were selected from two areas for isotopic investigations. The first group of samples was collected at different levels of the Late Precambrian-Cambrian succession in the Canning Land area: six from bed groups 9 to 13 of the Multicoloured Series, four from the Tillite Group and four from the fossiliferous Cambrian (upper Bastion Formation). All the samples were collected as far away as possible from faults and other tectonic or microtectonic complexities such as zones of conjugate slaty cleavage, zones of slickensides on bedding planes or zones of tension quartz veins (Caby, 1976b).

The second group of 12 samples was collected from a single exposure of the Multicoloured Series (top of bed group 7) exposed along the coast of Segelsällskapet Fjord.

All the investigated rocks lack a penetrative cleavage. With the exception of the second group, most samples represent thin layers of shaly composition within varied sequences of quartzites and dolomite.

The $< 2\,\mu$ mineral fraction was extracted by the usual methods, with special care in respect of the crushing technique to avoid any over-crushing of the coarse detrital fraction (C.N.R.S., 1978). In some samples the high carbonate content has necessitated a decarbonatation with HCl. Some samples were rejected because of a noticeable detrital component (small micas, feldspars etc.). In the $< 2\,\mu$ fraction, illite with a crystallinity index mainly in the range of 5 to

Table 1. Mineralogical and Rb-Sr isotopic data

Sample No	Size Fraction (1)	Illite %	Chlorite %	Crystallinity index	$\frac{I002}{I001}$ (2)	Rb (ppm) (3)	Sr (ppm) (3)	$\frac{^{87}Rb}{^{86}Sr}$ ±1.5% 1 σ	$\frac{^{87}Sr}{^{86}Sr}$ ±0.00020 1 σ	Formation and Location
	Fine fraction mineralogy					Rb/Sr isotopic data				
145324	W.R.	50	50	4.8	0.44	133.8	52.8	7.350	0.78032	Quartzite Series, Canning Land
	F.F.					187.5	13.62	39.91	0.96837	
145323	W.R.	75	25	5.0	0.41	78.5	94.6	2.403	0.73989	
	F.F.					158.8	12.65	36.38	0.96576	
145314	W.R.	90	10	5.5	0.33	309.4	24.59	34.47	0.95038	
145312	F.F.	85	15	5.1	0.37	213.4	20.41	30.31	0.92316	
145311	W.R.	85	15	4.8	0.32	302.2	28.04	27.903	0.8934	Multicoloured Series, Canning Land
	F.F.					196.6	25.86	22.038	0.86210	
145302	W.R.	85	15	4.7	0.36	290.6	51.7	16.304	0.82874	
	F.F.					191.7	28.78	19.300	0.85440	
145303	W.R.	60	40	7.2	0.39	66.4	73.1	2.555	0.73206	
	F.F.					140.8	10.20	40.04	0.06531	
145330	W.R.	95	5	4.7	0.41	123.0	59.5	5.128	0.75256	
145305	W.R.	75	25	6.2	0.37	122.6	24.26	14.648	0.83686	
	F.F.					150.3	30.0	14.526	0.82202	
145308	F.F.	25	75	n.d. (4)	n.d.(4)	50.7	69.0	2.129	0.74050	
145306	W.R.	55	45	4.7	0.44	35.7	85.3	1.123	0.72795	
	F.F.					110.3	99.4	3.217	0.74069	
145307	F.F.	95	5	6.5	0.41	253.6	164.5	4.468	0.74800	Tillite Group, Canning Land
145474	F.F.	100		7.0	0.45	140.9	230.2	1.774	0.72162	
145473	F.F.	100		6.9	0.41	201.7	33.2	17.628	0.82255	
145507	F.F.	90	10	8.0	0.50	203.0	33.0	17.836	0.83748	
145508	F.F.	100		6.5	0.41	186.9	27.15	19.951	0.84697	
145478	F.F.	65	35	5.5	0.46	165.9	58.7	8.194	0.76424	Cambrian Up. Bastion, Canning Land
145477	F.F.	90	10	6.5	0.38	151.9	119.7	3.680	0.73915	
145479	F.F.	85	15	5.6	0.35	140.4	103.0	3.951	0.74153	
145480	F.F.	85	15	5.7	0.29	174.4	104.9	4.820	0.75080	
213827(1)	F.F.	45	55	4.5	0.32	187.0	27.81	19.485	0.84323	Lower Multicoloured Series, Segelsällskapet Fj.
213827(2)	F.F.	75	25	4.6	0.30	240.7	20.34	34.30	0.89829	
213828A	F.F.	85	15	4.7	0.40	279.8	28.96	27.998	0.89601	
213830	F.F.	85	15	4.4	0.35	299.1	24.80	34.96	0.93970	
213831	F.F.	70	30	4.7	0.38	270.1	13.98	55.99	1.02898	
213833	F.F.	75	25	4.6	0.33	272.3	34.8	22.697	0.85757	

(1) W.R. whole rock; F.F. fraction smaller than 2 μ
(2) X-ray intensity ratio of the 5Å/10Å reflections of the illite
(3) obtained through isotope dilution
(4) n.d. not determined

7 is the chief mineral, but some samples also contain abundant chlorite (Table 1). This type of illite indicates that they are related to deep diagenetic conditions or to the anchizone of Kübler (1966).

Rb-Sr and K-Ar isotopic results

The Rb-Sr and K-Ar data were obtained using the techniques described by Clauer (1976) and Bonhomme *et al.* (1975), respectively. The Rb-Sr and K-Ar isotopic data are presented in Tables 1 and 2. Table 1 also shows the mineralogical data of the less than 2 μ fraction.

The Rb-Sr isochron has been calculated following Williamson (1968). All ages quoted have

Table 2. K-Ar isotopic data

Sample No	Size Fraction	K_2O(%)	^{40}Ar rad(%) / ^{40}Ar tot	^{40}Ar rad 10^{-6}cc/g	(Ma ± 2σ)
134314	F.F.	7.25	97.2	109.6	416 ± 10
145305	F.F.	4.95	96.7	91.7	498 ± 12
145307	F.F.	2.35	71.8	32.9	388 ± 14
145474	F.F.	5.24	96.9	86.8	452 ± 11
145477	F.F.	5.11	96.6	84.6	452 ± 11
145479	F.F.	5.62	97.3	91.3	444 ± 11
213827(1)	F.F.	4.21	94.9	63.5	415 ± 11
213827(2)	F.F.	5.71	95.6	92.1	437 ± 11
213828A	F.F.	5.65	96.7	103.5	493 ± 12

been determined, or recalculated from the literature, using the decay constants compiled by Steiger & Jäger (1977). All data are given the 2 σ confidence level.

When all the Rb-Sr analytical data are plotted in an isochron diagram the points scatter between two more or less parallel reference lines suggesting an age of the order of 450 Ma and initial ratio intercepts bracketed between 0.710 and 0.730 (fig. 2). When the specific sample locations of each of the formations studied are examined the data points show better alignment. This point is discussed below.

Lower part of Multicoloured Series, Segelsällskapet Fjord

Four of the six analysed fine fractions plot on a straight line indicating an age of 445 ± 49 Ma, with an initial $^{87}Sr/^{86}Sr$ ratio of 0.717 ± 0.017 and MSWD of 5.3 (fig. 2). The other samples show younger ages.

The K-Ar ages of two parts (1) and (2) of sample 213827 are 415 and 437 Ma, respectively (Table 2). These results are the reverse of the Rb-Sr data; here data for sample 213827 (1) lie on the 445 Ma line, while data for 213827 (2) provides the younger age.

Clauer (1976) and Bonhomme (1982) have defined the conditions for obtaining significant isotopic dates in slightly metamorphosed sequences. These are:

(1) There must be obvious field observations such as folding, schistosity;

(2) the thin sections must show evidence of phyllitic recrystallisation;

(3) the fine fraction association is generally composed of illite and chlorite;

(4) the illite crystallinity index must lie in the range of the anchimetamorphic to epimetamorphic domains; and

(5) the samples have to be collected within a small area.

The first three conditions are satisfied in the study described here. The present sampling was made within an interval of 20 m. This prevents strong isotopic inhomogeneities in the detrital material and allows for a smaller scatter of the isotopic points. The clay association and the crystallinity index of the illite are typical for anchimetamorphically transformed sediments.

As the stratigraphical age of the formation is older than the Cambrian, i.e. older than about 570 Ma, the isotopic age (445 ± 49 Ma) cannot be that of the sedimentation. The age is the same as that of metamorphic mica schists in other parts of the East Greenland Caledonian domain (Hansen & Tembusch, 1979) or of granites intruding it (Rex *et al.*, 1976), and thus this

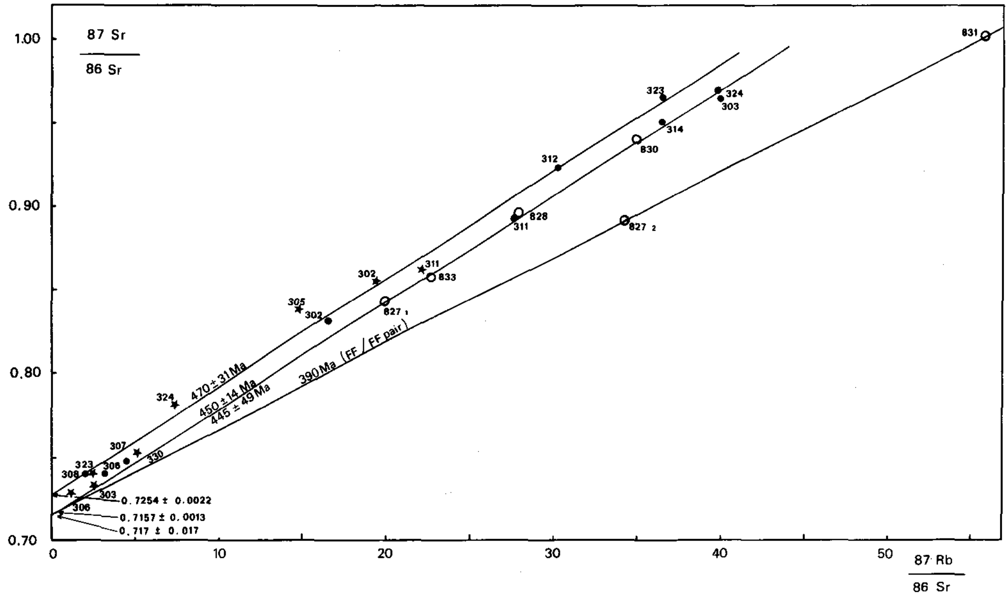


Fig. 2. Complete Rb-Sr isotopic diagram for the Quartzite Series and the lower Multicoloured Series. Dots: fine fraction from Canning Land samples; stars: whole rock data Segelsällskapet Fjord.

age is that of a Caledonian anchimetamorphic event affecting the Lower Multicoloured Series at Segelsällskapet Fjord.

In contrast to more metamorphosed sequences anchimetamorphic fine fractions remain highly sensitive to later thermo-tectonic events (Bonhomme, 1982). This explains the position of the two samples 213827 (2) and 213831 on the Rb-Sr diagram and the young K-Ar age of the 213827 (1) sample. This young K-Ar age may also be explained by the high amount of chlorite in the fine fraction, as chlorite is generally considered a bad chronometer (Bonhomme *et al.*, 1987). The K-Ar age of the sample 213828, 493 ± 12 Ma, can be explained by the occurrence of a detrital component of muscovitic type: I002/I001 = 0.40 (Esquevin, 1969).

Quartzite Series and lower part of Multicoloured Series in Canning Land

The Rb-Sr isotopic diagram shows that the data points are scattered, even when the samples of the two sequences are separated. Such a distribution of the data points may be looked at in two ways:

1. The points lie inside a parallelogram,
2. They lie on a set of more or less parallel isotopic lines.

Choosing empirically the second interpretation, mainly after Clauer & Bonhomme (1970) and Clauer (1976), three isotopic lines can be defined, all including both whole rocks and fine fractions.

The first line comprises three whole rocks and five fine fractions; it gives an age of 470 ± 31 Ma with $(^{87}Sr/^{86}Sr)_0$ of 0.7254 ± 0.0022 and MSWD = 45.5 (fig. 2).

The second line groups one whole rock and four fine fractions; it gives an age of 450 ± 14 Ma, with $(^{87}Sr/^{86}Sr)_0$ = 0.7157 ± 0.0013 and MSWD = 7.5 (fig. 2).

The third line is formed by three samples of the Lower Multicoloured Series: one whole rock and three fine fractions. It gives an age of 439 ± 10 Ma, with $(^{87}Sr/^{86}Sr)_0$ = 0.7204 ± 0.0004 and MSWD = 1.01 (fig. 3).

These three lines cannot be mathematicaly differentiated as all physical uncertainties overlap. However, the MSWD increases significantly when all the data points are considered. Thus, the observed dispersion must be related to incomplete isotopic homogenisation.

As at Segelsällskapet Fjord, some whole rock – fine fraction pairs give apparent Rb-Sr ages of the order of 400 Ma; e.g. the pair of sample 145324 gives an age of 407 Ma.

The K-Ar results scatter from 400 Ma to 500 Ma (Table 1).

These highly scattered data, as compared to those of samples from Segelsällskapet Fjord, will be discussed below, in an attempt to define an isotopic model for slightly metamorphosed sedimentary sequences.

Tillite Group and Cambrian, Canning Land

The Rb-Sr data points of the Tillite Group samples are scattered. This can be viewed as normal owing to the detrital character of that formation. Nevertheless, a fine fraction pair defined an age of 448 Ma (fig. 4).

The fine fractions of the Cambrian samples plot very near the lower isotopic line of the Quartzite Series and lower Multicoloured Series. Their K-Ar ages, as one sample of the Tillite Group, are all of the order of 450 Ma.

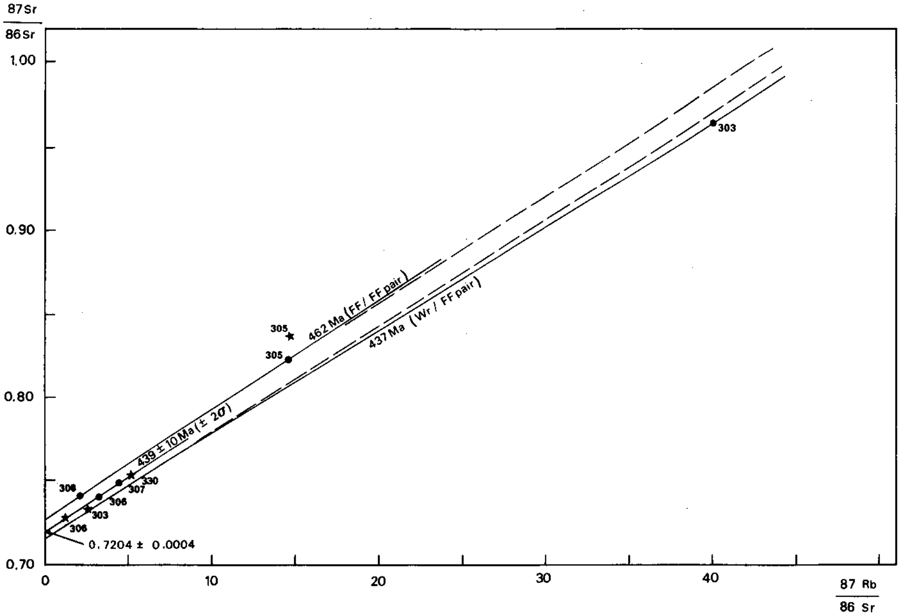


Fig. 3. Rb-Sr isotopic diagram for the basal limestone-dolomite member of the lower Multicoloured Series, Canning Land. Dots: fine fractions; stars: whole rocks.

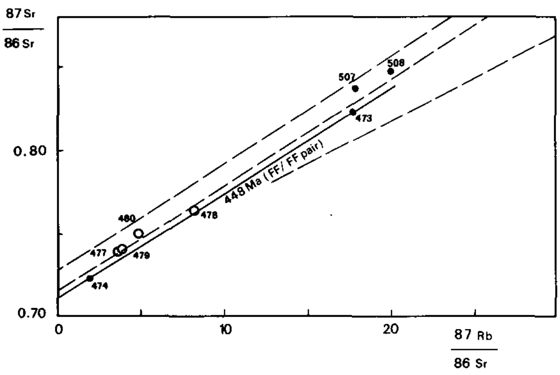


Fig. 4. Rb-Sr isotopic diagram for the Tillite Group and Cambrian from Canning Land. Dashed line is the lower Multicoloured Series reference isochron. Dots: fine fraction from the Tillite Group samples; open circles: fine fractions from the Cambrian.

Discussion

The various sequences show only one well documented event at about 450 Ma using both Rb-Sr and K-Ar isotopic techniques.

The Rb-Sr isotopic line of the Segelsällskapet Fjord samples is unique for four out of the six samples with a low MSWD related to the ± 0.0002 constraint on the $^{87}Sr/^{86}Sr$ ratios, the two samples 213827(2) and 213831 being reset owing to their low Sr content. In contrast the isotopic data from the other locations may be considered in terms of either a scatter of points, or as a group of more or less parallel isochrons.

If we assume that the data points are only scattered, then the mean slope of the parallelogram containing them defines a reference isochron whose age would also be of the order of 450 Ma. The specific position of the samples depends mainly on the ratio between the detrital and carbonate fractions. The more detrital samples lie on the higher isotopic line and the carbonate fractions on the lower. The main reasons for the apparent isotopic dispersion are that (1) these samples come from a wide area; and consequently (2) their detrital contribution scatters widely in connection with both the stratigraphic level and the palaeogeography. The presence of zircon placers (Peucat *et al.,* 1985) of older age confirms this deduction.

The scatter of the data points of a regionally slightly metamorphosed sequence depends also on the grade of metamorphism and on the detrital minerals. Some minerals are easily transformed under diagenetic to anchimetamorphic conditions; kaolinite, interlayered smectites (Dunoyer de Segonzac, 1969), biotites and K-feldspars (Perry & Hower, 1972).

The transformation of the detrital minerals will also increase with the increasing grade of metamorphism. The most resistant mineral to such a transformation is muscovite, and muscovite-rich detrital samples will show higher isotopic ratios when analysed in total rock. The studied sequence also contains accumulations of detrital muscovites, mainly in the Quartzite Series and in the Alpefjord Series (Peucat *et al.,* 1985).

Thus, the Quartzite Series and also the Tillite Group and the lower Multicoloured Series in the present stage of anchimetamorphism cannot be isotopically homogenised, or if so only on a very local scale as at Segelsällskapet Fjord. Their excess of radiogenic isotopes (^{40}Ar and ^{87}Sr) is redistributed in the metamorphic fluids, and may escape or enter newly formed minerals. If so, the initial ratio of the isotopic data of newly formed minerals will increase and $(^{40}Ar/^{36}Ar)_0$ will be higher than 295.5 and $(^{87}Sr/^{86}Sr)_0$ will be higher than the contemporary $^{87}Sr/^{86}Sr$ ratio of the sea water. Such a model of isotopic redistribution has been defined by Bonhomme & Prevot (1968) and Clauer (1976).

Clauer & Bonhomme (1970), Clauer (1976) and Bonhomme & Hassenforder (1985) have observed that the isotopic diagram can be reduced to two isochrons. The data points do not scatter around one isochron following a Gauss distribution, but mainly define parallel lines. Thus, the various factors that can have an influence are:

1. the amount of detrital, mainly muscovitic minerals,
2. the carbonate versus detritic ratio,
3. the wide area of sample collection,
4. the thickness of the sequence,
5. the model isotopic redistribution,
6. and the already published examples, lead to the choice of the multi-line model, instead of a reference isotopic line.

The samples containing high amounts of chlorite are situated in particular isotopic positions. The sample 145308, for instance, which belongs to a system showing a rather low $(^{87}Sr/^{86}Sr)_0$ ratio, is situated significantly above the 439 Ma isotopic line. This position may be explained either by the sensitivity of the chlorite minerals to any event, allowing acceptance of mobile radiogenic strontium, or to the poor retentivity of the chlorite to any radiogenic isotope (J. Esquevin, personal communication, 1982).

Some samples lie above the 450 Ma lines. For instance, the sample 145305, which belongs to a geological system showing a low intercept is situated above the isochron, both in fine fraction and whole rock. Although not differing from the other samples mineralogically and sedimentologically, the high position of the analytical point may be explained by the presence of detrital material, incompletely open to isotopic redistribution. The high K-Ar age (498 Ma) may also be related to the detrital content.

Ages of the order of 400 Ma, obtained by both Rb-Sr and K-Ar methods, are observed locally. For instance, the two parts of sample 213827, (1) red shale and (2) green shale, only 3 cm apart, show Rb-Sr ages of 450 and 390 Ma, respectively. The corresponding K-Ar ages are 415 and 427 Ma. This means that the two isotopic responses are opposite. With our present knowledge there is no plausible explanation for this discrepancy. Nevertheless, the extreme sensitivity of the K-Ar isotopic system to any recrystallisation (Bonhomme, 1982) indicates that one must admit the probability of an event at about 390 Ma rather than cooling ages, which would show a profile with continuous ages from 450 to 400 Ma. The importance of these movements of Devonian age is demonstrated by vertical faulting which uplifted the Stauning Alper plutonic complex (vertical shear zones reaching the biotite isograd), and by the large-scale westward thrusting of the central metamorphic complex with a basal sole of retrogressive blastomylonites with minute biotite and chlorite onto the Gletscherland Complex (Higgins *et al.*, 1981).

In conclusion, both field, mineralogical and isotopic work suggests that the sediments of the Upper Eleonore Bay Group and the Cambrian have been metamorphosed at the anchimetamorphic to strongly diagenetic grade at about 450 Ma. Very locally, and depending on the mineralogy of the fine fraction and on the isotopic technique, there is some evidence consistent with a low intensity event at nearly 400 Ma. The ages are consistent with those generally known as defining the Caledonian orogeny, especially in East Greenland (Haller, 1970; Hansen & Tembusch, 1979; Rex & Gledhill, 1981).

Comparison with previous isotopic work

In the East Greenland Caledonian domain a number of metasedimentary formations of much higher metamorphic grade have been analysed by the Rb-Sr whole rock method. Hansen *et al.* (1978) and Hansen & Tembusch (1979) obtained Rb-Sr isochrons on mica schists and kyanite schists. The ages of 440 Ma are believed to reflect a complete isotopic resetting during Caledonian times.

Several granitic bodies have also been dated by Rb-Sr whole rock isochrons. For instance Rex *et al.* (1976) have dated at 445 ± 5 Ma the Forsblads Fjord granite regarded as one of the youngest granitic bodies by Haller (1958). Hansen & Tembusch (1979) have dated the intrusion of the east Milne Land granodiorite at 453 ± 23 Ma regarded as the oldest plutonic rock in east Milne Land.

Age studies have also been carried out on granitic bodies using the U/Pb method. For instance, Oberli & Steiger (1973) have recorded ages of 450 Ma on monazites from the Bjørneøer migmatite and on zircons of a granite dyke cutting the migmatites; this age is regarded as that of the end of the Caledonian metamorphism. However, an age of 437 ± 5 Ma is shown by the lower intersection of the concondia diagram of a sample of monazites from Renodden, and a lower intersection age of 421 ± 15 Ma is also defined using the zircons of a granodiorite from the Stauning Alper (Hansen *et al.*, 1978; Hansen & Steiger, 1976).

With respect to K-Ar data, both ages of 450 – 440 Ma, and younger ages of the order or 400 Ma (Rex *et al.*, 1976) are found; for example a muscovite of a granitic body intruded along a fault between gneisses and metasediments has given an age of nearly 415 Ma. The K-Ar ages of 450 Ma within the central metamorphic complex have been regarded by these authors as cooling ages related to the main Caledonian events, whereas the ages of about 400 Ma might correspond to a later event.

These results have been listed here to show that if the main metamorphism is dated at about 450 Ma there is a good probability of a weak event at 415 – 400 Ma. This leads to the same conclusion as our study.

Conclusions

Mineralogical and isotopic data have been obtained on Upper Proterozoic to lowermost Cambrian rocks in Canning Land and Segelsällskapet Fjord.

(1) The mineralogy of the fine fraction shows that the sediments are anchimetamorphic or strongly diagenetic.

(2) The slight metamorphism and the diagenesis have been dated at 450 Ma by both Rb-Sr and K-Ar methods. They correspond to the main Caledonian event affecting these formations as demonstrated through the geological structural and petrographic evidence, and through published geochronological data.

(3) A later event may be suggested by both Rb-Sr and K-Ar methods at about 400 Ma. We tentatively link this event to late Caledonian high level tectonics in the fold belt.

(4) This study confirms the feasibility of dating metamorphic events of very weak intensities through Rb-Sr and K-Ar isotopic techniques.

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