# Rb-Sr whole rock 'ages' from reworked basement gneisses in the Umanak area, central West Greenland

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Morten C. Andersen and T. C. R. Pulvertaft: Rb-Sr whole rock 'ages' from reworked basement gneisses in the Umanak area, central West Greenland. *Bull. geol. Soc. Denmark,* vol. 34, pp. 205–212. Copenhagen, December, 20th, 1985. https://doi.org/10.37570/bgsd-1985-34-16

This note reports the results of a Rb-Sr whole rock study of two of the main gneiss units in the southern part of the Rinkian mobile belt, central West Greenland. These gneisses belong to the basement upon which the metasedimentary formations of the Karrat Group were deposited. One of these formations, the Marmorilik marble formation, can be traced from its type locality where a primary unconformity at the base of the formation is preserved, into the southern part of the Umanak area where both the marble and the basement gneisses have been involved in at least two phases of Rinkian recumbent folding. Both the gneiss units studied were sampled in areas where demonstrably post-Marmorilik Formation (i.e. Rinkian) recumbent folding is conspicuous.

The one gneiss unit is a granodioritic biotite gneiss which is the main gneiss type in the Umanak area. Samples of this collected within an area of 50 $m^2$ yielded an isochron age of 2629 ± 246 Ma, $Sr_i$ 0.7033 ± 0.0010 (2σ errors). The other gneiss studied is granodioritic augen gneiss known from earlier dating in an area of low Rinkian deformation to be at least 2500 Ma old. Samples of this gneiss collected in an area of very strong Rinkian deformation did not give an isochron but scatter around a 2500 Ma reference line.

Although this study has not yielded accurate ages for the gneiss units investigated, it has at least provided further confirmation that the basement gneisses of the Umanak area are Archaean. Furthermore, the results show that recumbent folding and strong deformation under amphibolite facies conditions can disturb but will not necessarily reset Rb-Sr whole rock isochrons – an observation that accords with results from the gneissic cores of the Pennine nappes in the Alps.

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*February 26th, 1985.*

The Precambrian rocks of the Umanak area, central West Greenland, belong to the southern part of the Rinkian mobile belt (Fig. 1). This mobile belt is distinguished by an extensive and thick supracrustal group, the Karrat Group, which lies on a gneiss basement that rises into the supracrustal cover in domes and the cores of nappes. In its type area the Karrat Group comprises two formations: the Qeqertarssuaq Formation (lower) which varies in thickness from a few tens of metres to more than two kilometres and consists mainly of quartzite and pelitic schist, and the Nukavsak Formation (upper), a more than 4.5 km thick flysch sequence. In the southern part of the Rinkian belt the clastic Qeqertarssuaq Formation gives way to a *c.* 2 km thick carbonate sequence, the Marmorilik Formation. The primary relations between basement and cover are only seen in the Mârmorilik area where an angular unconformity is locally preserved at the base of the Marmorilik Formation (Garde & Pulvertaft 1976).

The first Rb-Sr isochron age determinations on rocks from the Umanak area (Kalsbeek 1981) were carried out in order to 1) establish the age of the gneiss basement which was thought, but had yet to be proved, to be Archaean, 2) bracket the age of deposition of the Marmorilik Formation, the most important of the supracrustal cover formations from both an economic and a scientific point of view (Pedersen 1980; Garde 1978, 1979). The age of the basement and a maximum age for the Marmorilik Formation was established from samples from the Tasiussaq megacryst granodiorite collected at the type locality, a little below the base of the Marmorilik Formation (Fig. 2). Here the primary unconformity at the base of the Marmorilik Formation is well pre-

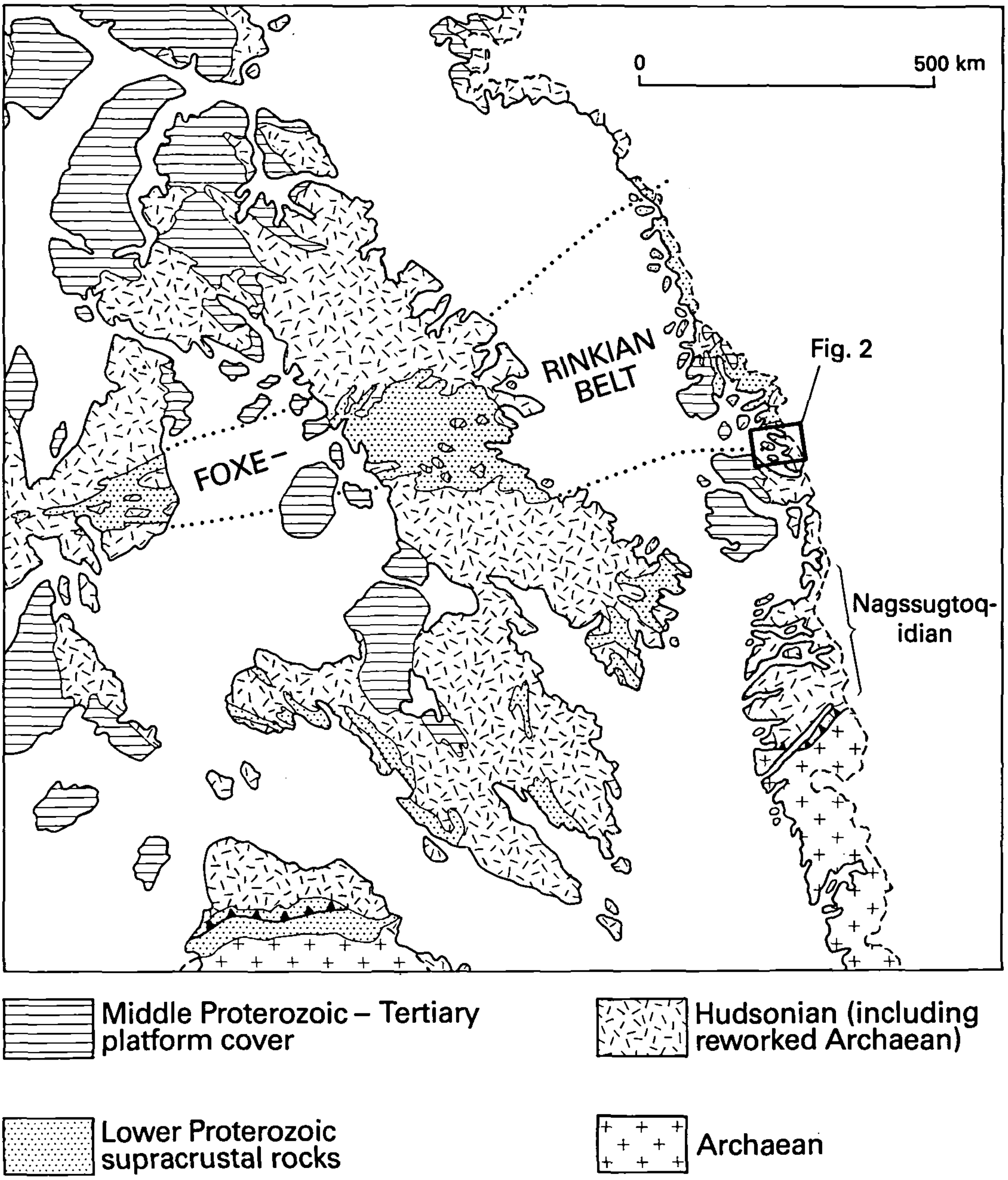


Fig. 1. Map showing the position of the Umanak area with regard to the regional geology of west Greenland and eastern Canada. The pre-drift fit is from Le Pichon et al. (1977), modified to avoid overlap in the Canadian arctic islands.

served and the Tasiussaq megacryst granodiorite almost undeformed, so the influence of Rinkian processes should be minimal. The result – 2570 ± 90 Ma, $Sr_i$ 0.7049 ± 0.0011 – confirmed the Archaean age of the basement, although it is not clear whether this age dates the intrusion of the granodiorite or is the result of late Archaean metamorphism (Kalsbeek 1981, p. 209).

The minimum age of the Marmorilik Formation was obtained by dating fine-grained biotite semipelite from the basal member of the formation at Magdlak. This gave a Rb-Sr isochron age

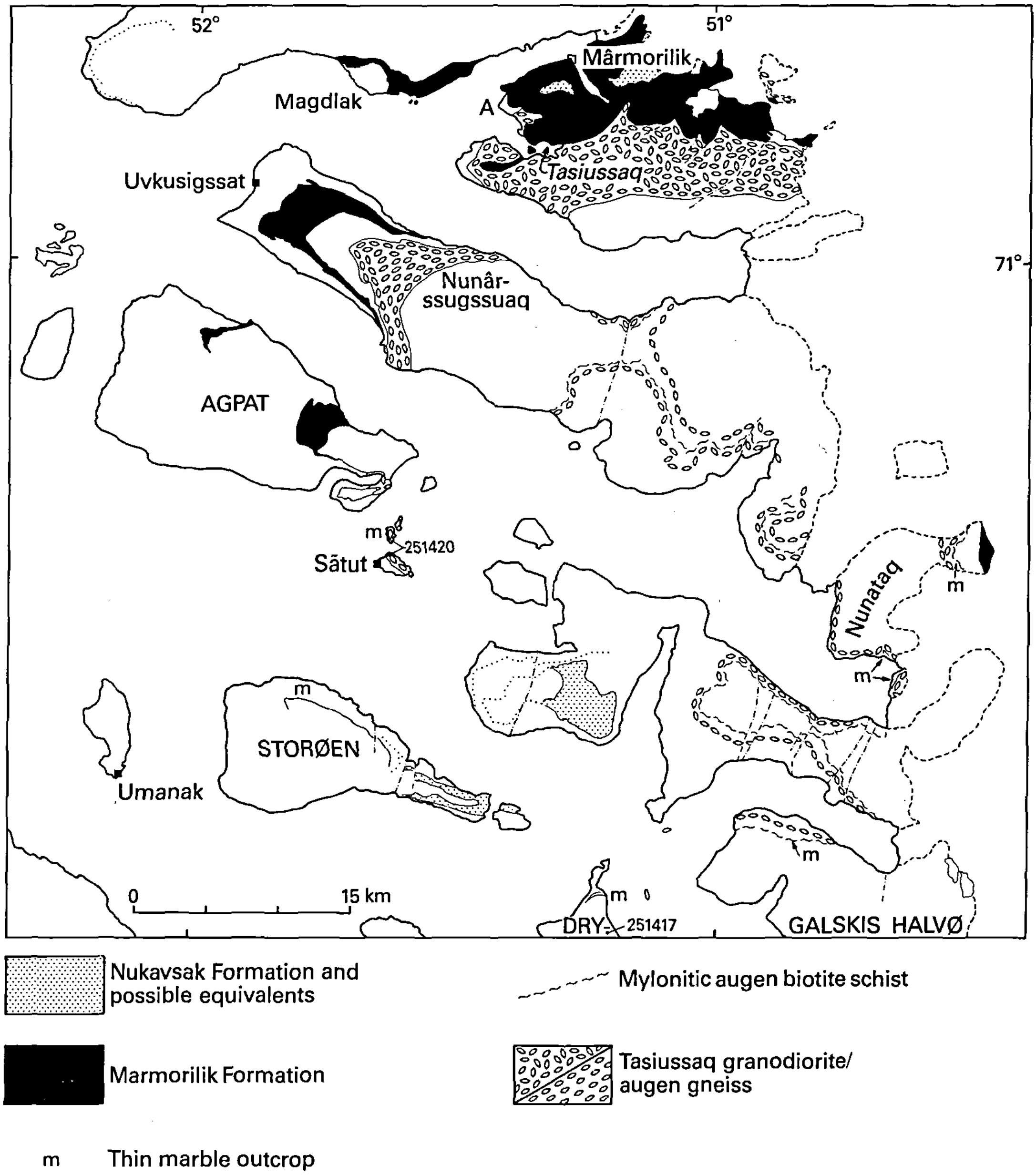


Fig. 2. Map of the Umanak area showing the main outcrops of Lower Proterozoic supracrustal rocks, the Tasiussaq granodiorite/ augen gneiss, and the localities of the samples studied.

of 1690 Ma, which is close to the K-Ar biotite ages obtained by Larsen & Møller (1968) for both basement and cover rocks in the area. These ages are believed to reflect the close of Rinkian deformation and metamorphism.

The purpose of the Rb-Sr whole rock isotope study reported in this note was to supplement Kalsbeek's dates with a date on the most widespread gneiss unit in the Umanak area, a fine- to medium-grained granodioritic biotite gneiss. This gneiss type is not however found in areas where the basal unconformity to the Marmorilik Formation is preserved, but is extensive in areas where strong Rinkian folding and deformation has taken place. Thus there was a risk that the isochron would be disturbed and difficult to interpret. A second dating was therefore carried out with the specific purpose of finding out whether very strong, demonstrably Rinkian, folding and deformation could reset the Rb-Sr isochron in a granitoid rock. For this purpose the Tasiussaq granodiorite is ideal, for it can be followed together with the Marmorilik Formation southwards from Tasiussaq to the eastern end of Agpat island where the Marmorilik Formation has been folded into the basement in a thin recumbent syncline and subsequently refolded (Figs 2 and 4). The development of these major Rinkian structures was accompanied by a strong deformation of the Tasiussaq granodiorite so that at the eastern end of Agpat and on the islands to the south this unit appears as a well foliated augen gneiss. It is this augen gneiss that has been studied.

## Procedure

Samples weighing about 4 kg were crushed and split. Rb/Sr ratios were measured on two powder tablets of each sample with the Philips PW 1410/20 X-ray fluorescence spectrometer at the Geological Institute, University of Copenhagen. Measurements on each pair of tablets agreed to within 1%, with one exception where the difference was 1.3%. USGS G-2 and GSP-1 were used as standards. The $^{87}Sr/^{86}Sr$ ratios were measured on unspiked Sr, separated by standard ion exchange techniques, with the Varian Mat TH5 mass spectrometer also at the Geological Institute of the University of Copenhagen. While the precision of the mass spectrometer measurements is of the order of $\pm 0.01\%$, a number of duplicate analyses of independent chemical Sr separations suggest that the overall precision of the $^{87}Sr/^{86}Sr$ measurements is 0.0002. The measurements were normalised and are reported relative to the Eimer and Amend $SrCO_3$ standard $^{87}Sr/^{86}Sr = 0.7080$.

The isochron calculations were performed according to the method described by McIntyre et al. (1966), using 1% and 0.0002 for the precision of the Rb/Sr and $^{87}Sr/^{86}Sr$ ratios respectively. All errors quoted are at the 2σ-level. Ages were calculated using $\lambda^{87}Rb = 1.42 \times 10^{-11}\ yr^{-1}$ (Steiger & Jäger 1977).

## Biotite gneiss

This widespread gneiss unit was sampled on the plateau above the spectacular recumbent fold on the west side of Drygalskis Halvø (Escher & Pulvertaft 1976, fig. 109). Since this fold affects a thin marble horizon believed to be infolded Marmorilik Formation (Pulvertaft in press), the structure is regarded as a result of Rinkian folding. Fourteen samples were collected within a 5 × 10 m area, and of these the six giving the maximum spread in Rb/Sr ratios were selected for Sr isotope study. The sampling locality was chosen because the gneiss here is fresh, relatively free of leucocratic veins, but in every other way representative of the gneiss forming wide areas on Drygalskis Halvø.

The rock is fine- to medium-grained and has a granoblastic to lepidoblastic texture with a parallel orientation of biotite. Plagioclase $An_{20}$ is the main mineral and is seen as up to 2 mm large anhedral grains with albite and pericline twinning. Larger plagioclase patches are polygonised and consist of up to 1 mm grains with *c.* 120° triple junctions. Microcline occurs in up to 0.5 mm grains with perthitic texture. Both feldspars are weakly altered (sericitised). Quartz forms up to 2 mm large anhedral grains which show conspicuous deformation and may give the rocks a crude

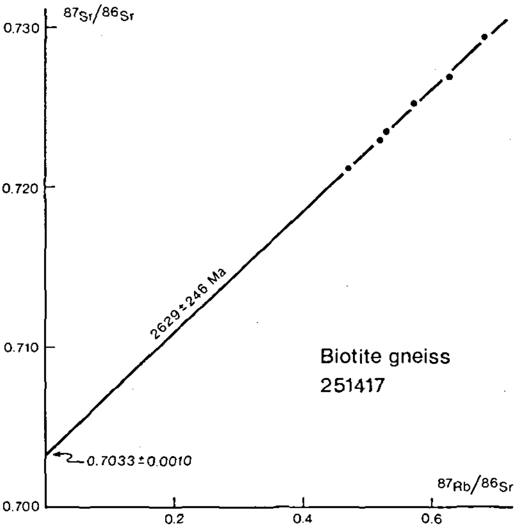


Fig. 3. Rb-Sr isochron diagram for the biotite gneiss in western Drygalskis Halvø.

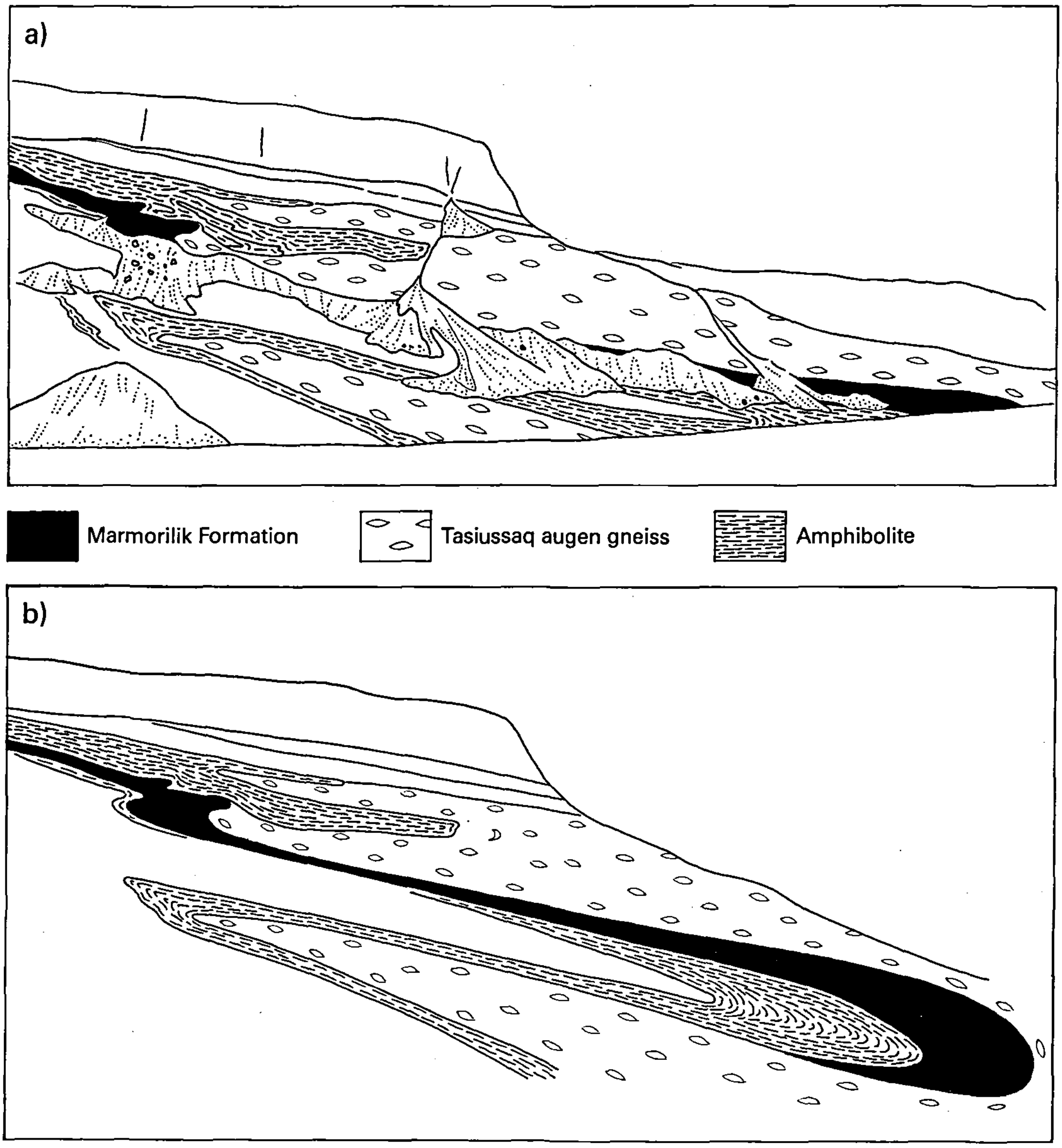


Fig. 4. Field sketch (a) and extrapolation (b) of the structures seen in the southeast facing slope of the east end of Agpat island.

linear fabric. Brown biotite forms flakes up to 1 mm long and is locally replaced along cleavage planes by chlorite. Zircon and apatite are accessories.

The Rb-Sr analytical data for the biotite gneiss are plotted on an isochron diagram in Fig. 3. The data plot on or close to an isochron line (MSWD 0.27) giving an age of 2629 ± 246 Ma and $Sr_i$ 0.7033 ± 0.0010. The wide margins of error are due to the restricted range of Rb/Sr values.

In spite of the wide margin of error, the data show that the typical gneiss of the Umanak area is of Archaean age. Rinkian recumbent folding and the imposition of a Rinkian quartz fabric failed to impose a Rinkian age on the Rb-Sr whole rock isotope system.

## The Tasiussaq granodioritic augen gneiss

The Tasiussaq granodioritic augen gneiss was sampled on the islands Sātut and Sātorqigsut (Sātorqigsut is the island immediately north of Sātut), which lie south of the eastern end of Agpat island. The Rinkian structural development here can be seen from the structures displayed on the southeast slopes at the eastern end of Agpat (Fig. 4). This structural development has altered the Tasiussaq granodiorite, which in its type area is only slightly deformed, into a well foliated augen gneiss or, where the augen have been destroyed, into a thinly layered gneiss (Fig. 5). To judge from the mineral assemblages in the Marmorilik Formation (tremolite marble, with diopside skarn at the contact between marble and the basal quartzite), this deformation took place under amphibolite facies conditions, but there is no evidence of Rinkian anatexis in this area.

In thin section the rock shown in Fig. 5 has a lepidoblastic texture with obvious signs of deformation. The large (<5 mm) microcline grains show bent twinning and deformed string perthite lamellae. Quartz occurs in lenticular aggregates of strained crystals and also in strained single crystals oriented parallel to the layering. Plagioclase $An_{23}$ forms grains up to 3 mm in size, but does not show the same degree of deformation as microcline and quartz. Myrmekite is abundant at the margins of microcline grains. Much of the rock is fine-grained, the fine material tending to

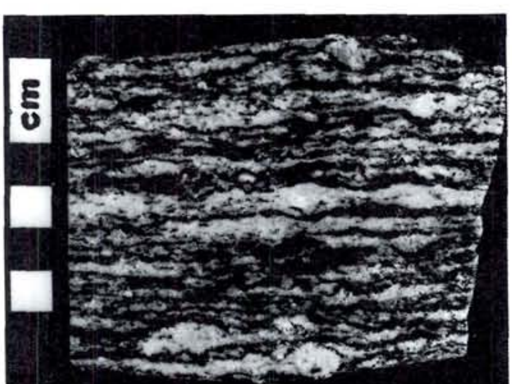

Fig. 5. Tasiussaq augen gneiss, Sātut. Photograph of one of the samples plotted on Fig. 6.

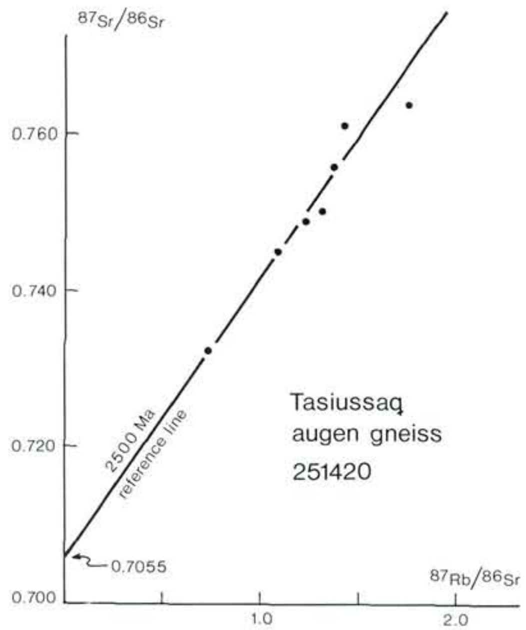

Fig. 6. Rb-Sr isochron diagram (with 2500 Ma reference line) for the Tasiussaq augen gneiss, Sātut and Sātorqigsut.

be concentrated in layers parallel to the dark schlieren and foliae. These dark areas are composed of biotite, green hornblende, sphene with lamellar twinning, and magnetite. Epidote, apatite and zircon are accessories.

The seven samples showing the greatest spread of Rb/Sr ratios were selected for Sr isotope analysis; the Rb-Sr isotopic data for these is shown in the diagram Fig. 6. As can be seen from this figure, the samples do not plot on a straight line but scatter around a reference line for 2500 Ma and $Sr_i$ 0.7055. While the results obtained cannot be said to have actually dated anything, they do very clearly betray the pre-Rinkian age of the augen gneiss. Amphibolite facies metamorphism, recumbent folding, and strong penetrative deformation and recrystallisation during the Rinkian were not enough to homogenise the Rb-Sr whole rock isotopic system and reset the isochron for samples collected within an area of 1.5 $km^2$.

## Discussion

The results presented here not only add to the body of published isotopic age data for the basement gneisses of the Rinkian mobile belt, but also provide further evidence that preservation of an old Rb-Sr whole rock 'fingerprint' need not mean that no younger folding and deformation has affected the area. In the present study it can be shown that the Archaean granitoids investigated have undergone Rinkian (~Hudsonian) recumbent folding and deformation accompanied by recrystallisation and the formation of a new fabric, under conditions of amphibolite facies metamorphism. In spite of this the Archaean isotopic imprint on the rocks is retained. This accords with experience gained in the Sveconorwegian belt in southeast Norway (Skjernaa & Pedersen 1982), and also in the Pennine zone of the Swiss Alps, an area with many similarities to the southern part of the Rinkian belt. In the gneissic cores of the Pennine nappes preservation of pre-Alpine whole rock isochron patterns is the rule and resetting the exception (Jäger 1970, p. 170). In the Western Gneiss Region of the Norwegian Caledonides suggestions that the preservation of Precambrian (Svecofennian) Rb-Sr whole rock isochron ages in the gneiss precludes the possibility of major Caledonian metamorphism and deformation in the area have been disputed by Krill & Griffin (1981). The present study in an area where the field relations are indisputable lends support to Krill & Griffin's contention that the old isochrons obtained in the Western Gneiss Region are insufficient grounds for rejecting the possibility of substantial Caledonian influence in the region.

In a study of the Rb-Sr isotopic systems in a shear zone in the West Greenland Nagssugtoqides, Hickman & Glassley (1984) conclude that fluid transport is a major factor in the resetting of Rb-Sr isotopic systems, and state that rocks showing the highest strain do not invariably show the most disturbed isotopic systems. Limited fluid transport within the large homogeneous units investigated in the present study is therefore the most likely explanation for the low degree of Rb-Sr isotopic response to the extensive Rinkian deformation in the area.

Studies in areas of reworking of older granitoid rocks have shown that rehomogenisation of Rb-Sr isotopic systems and resetting of isochrons can have taken place within a small area but be indistinct if the samples investigated were collected over a wide area (Kalsbeek & Pidgeon 1980, Brattli et al. 1982). It is therefore worth stressing that in the present study the best pre-Rinkian isochron was obtained from samples collected within an area of 50 $m^2$.

Acknowledgements. The authors would like to thank F. Kalsbeek and O. Larsen for advice and discussions during the course of the work. The paper is published with permission from the Director of the Geological Survey of Greenland.

## Dansk Sammendrag

Artiklen behandler resultaterne af en Rb-Sr whole rock undersøgelse af to vigtige gnejs-enheder fra den sydlige del af Rinkiderne i det centrale Vestgrønland. Disse gnejser tilhører basementet, på hvilket metasedimentære formationer tilhørende Karrat Gruppen blev aflejret. En af disse formationer – Marmorilik marmor formationen – kan følges fra typelokaliteten, hvor en primær unconformity er bevaret ved basis, ind i den sydlige del af Umanak-området, hvor både marmor og basementgnejser har deltaget i mindst to foldefaser under den Rinkidiske orogenese. Begge de undersøgte gnejs-enheder er prøvetaget i områder, hvor tydelig post-Marmorilik formation (d.v.s. Rinkidisk) foldning er markant.

Den ene gnejs-enhed er en granodioritisk biotitgnejs, som i øvrigt er den vigtigste gnejstype i Umanak-området. Prøver indsamlet over et 50 $m^2$ stort område giver en isochron-alder på 2629 ± 246 Ma og $Sr_i$ = 0,7033 ± 0,0010. Den anden undersøgte gnejstype er en granodioritisk øjegnejs, der tidligere er prøvetaget i et område med lav Rinkidisk deformationsgrad. Rb-Sr whole rock undersøgelser udført på disse prøver viser, at gnejsen har en alder på minimum 2500 Ma, mens de nye prøver, der er indsamlet i et område med intens Rinkidisk deformation, ikke giver nogen isochron, men spreder sig omkring en 2500 Ma referencelinie.

Denne undersøgelse har ikke giver præcise aldre på de undersøgte gnejs-enheder, men har dog yderligere bekræftet, at basementgnejserne i Umanak-området er archæiske. Desuden viser resultaterne, at foldning og intens deformation under amfibolitfacies-forhold kan forstyrre, men ikke nødvendigvis forandre, Rb-Sr whole rock isochroner. Dette er i overensstemmelse med resultater fra gnejs-kerner i de penninske napper i Alperne.

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