Research Note

An Early Proterozoic U-Pb zircon age from an Eskolabreen Formation gneiss in southern Ny Friesland, Spitsbergen

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A preliminary U/Pb zircon age determination has been carried out on a grey gneiss of the Eskolabreen Formation, the lowest observable lithostratigraphic unit of Precambrian metamorphic rocks in southern Ny Friesland, NE Spitsbergen. The obtained age, ca. 2,400 Ma, is considered to be a metamorphic age and suggests an Early Proterozoic tectonothermal event.

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Introduction

Recent geochronological works on the pre-Caledonian basement of Svalbard have revealed not only a late Middle Proterozoic tectonothermal event, the Grenvillian (Peucat et al. 1989; Tebenkov et al. 1991; Balashov et al. 1992; Gee et al. in press), but also a late Early Proterozoic event (Gee et al. 1992; Gavrilenko & Kamensky 1992) and some Early Proterozoic and older U-Pb zircon upper intercept ages (Peucat et al. 1989; Balashov et al. 1992) and Sm-Nd model ages (Bernard-Griffiths et al. 1993).

Since the Ny Friesland area, northeastern Spitsbergen, has complex structures (Manby 1990; Gee et al. 1992) and the largest distribution of the pre-Devonian crystalline basement, Early Proterozoic rocks can naturally be expected. This note reports an Early Proterozoic U-Pb zircon age obtained from a gneiss of the Eskolabreen Formation, the lowest lithostratigraphic division of the basement rock succession as defined by Harland et al. (1966).

Geological setting

Ny Friesland occupies the middle part of the basement areas of northern Svalbard (Fig. 1). The structure in the southern part of Ny Friesland is dominated by an asymmetric antiform, the Atomfjella antiform (Harland 1959). The axis plunges gently to the north. The western limb of the antiform is cut by a steep fault zone, dipping 50–80° to the west, which is a part of the N-S trending Billefjorden Fault Zone (Harland et al. 1974), the latter down throws to the west. Some Carboniferous cover has been preserved on the basement block in the east side of Austfjorden. The eastern limb of the antiform is cut by a steep E dipping, partly thrust, fault within the antiform and the Finlandveggen Group is in contact with the Harkerbreen Group (Table 1) by this fault. Along the eastern margin of the antiform the Harkerbreen Group is in contact with the Mossel series (Krasil'ščikov 1973) or the Planetfjella Group of the upper Stubendorffbreen Supergroup (Harland et al. 1966) by a W-dipping thrust fault.

The core of the antiform is composed of the Smutsbreen and the Eskolabreen Formations of the Finlandveggen Group (Harland et al. 1966; Krasil'ščikov 1973; Harland 1985, 1992). The Smutsbreen Formation consists of grey biotite gneisses with or without garnet and distinctive marble layers. The latter are in both the lower and upper parts, and small amounts of calc-silicate-gneisses and amphibolites also present. The Eskolabreen Formation is the lowest observable lithostratigraphic unit and is composed of garnet-hornblende-biotite- and hornblende-biotite gneisses, amphibolites and granitic gneisses. These rocks have upper amphibolite facies mineral assemblages of high temperature series with andalusite-sillimanite, while the rocks of this formation in the limbs have kyanite-garnet-mica assemblages without sillimanite, indicating a lower temperature condition than in the core and an intermediate temperature-pressure series.

The Flåtan granite in the northern part of Ny Friesland (Fig. 1) has a 1,788 + 53/-45 Ma U-Pb zircon isochron age. It also

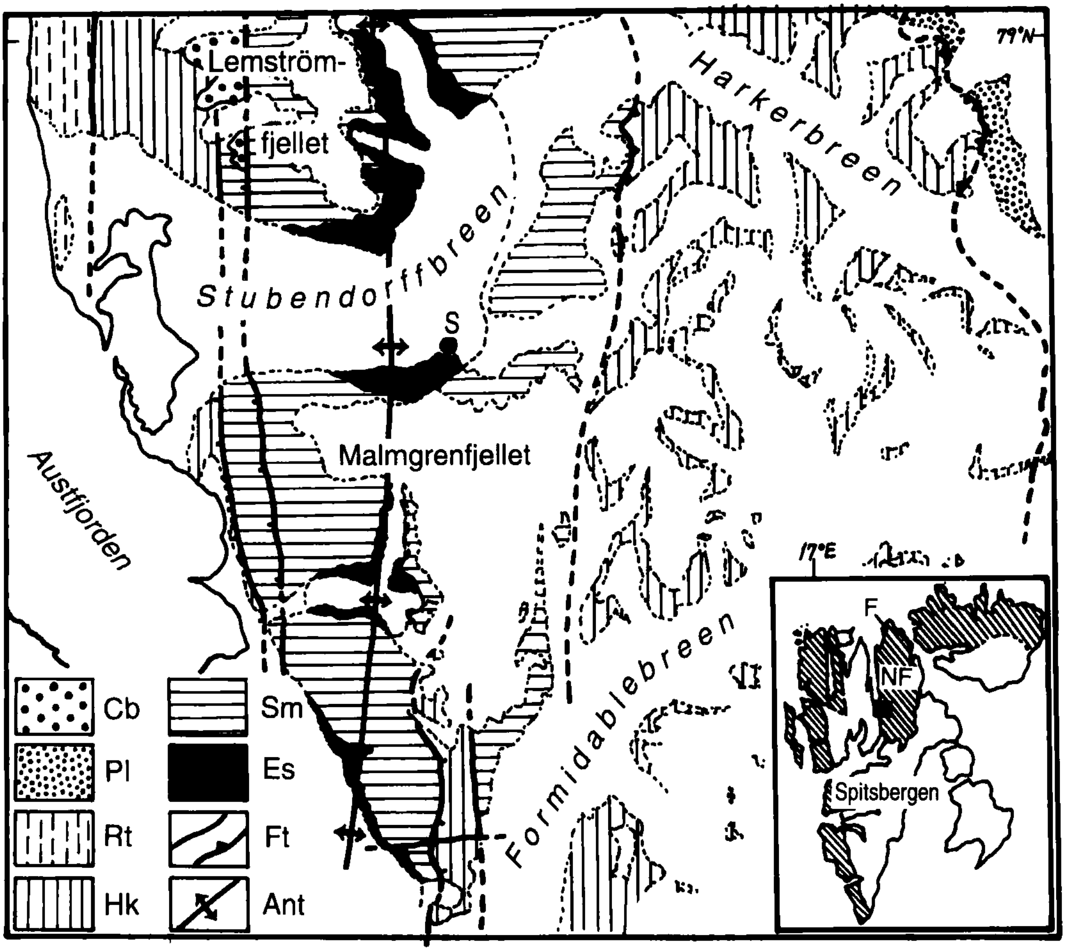

Fig. 1. Generalized geological map of southern Ny Friesland, with the sample locality. Inserted map: Solid square = map area, dashed area = pre-Devonian basement, NF = Ny Friesland, F = Flåtan granite. Legend: Cb = Carboniferous, Pl = Planetfjella Group or Mossel series, Rt = Rittervatnet Formation, Hk = Polhem or Harkerbreen Formation, Sm = Smutsbreen Formation, Es = Eskolabreen Formation, Ft = fault and thrust, Ant = Atomfjella antiform. S with a solid circle = sample locality.

yielded zircon single grain ages of ca. 1,700 Ma (Gee et al. 1992). This granite possibly intruded in the gneisses and amphibolites of the Polhem Formation in the lower part of the Harkerbreen Group (Table 1). Thus the protoliths of the gneisses and amphibolites are of Early Proterozoic. Ultramafic rocks separating the Polhem Formation from the Planetfjella Group have yielded a ca. 1.8 Ga age and a biotite concentrated rock adjacent to them gives an age of 500 Ma, both by the K-Ar method (Gavrilenko & Kamensky 1992), though the reliability of these K-Ar data is a matter of debate.

This note presents a preliminary U-Pb zircon age obtained from an Eskolabreen Formation gneiss in southern Ny Friesland. This age was orally presented by Balashov in August 1993 at Turku, Finland.

Materials and methods

Sample description

A grey gneiss (ca. 30 kg) from the Eskolabreen Formation in the middle-southern side of Stubendorffbreen has been used for this isotopic study. The locality is shown in Fig. 1. The rock is a coarse-grained, feldspar porphyroblastic, garnet-hornblende-biotite gneiss with a modal composition of 25–30% quartz, 25–30% plagioclase (An_{20-25}), 30–40% K-feldspar, 10% biotite, 1–2% hornblende and 1–2% garnet with accessories of apatite, zircon, monazite and opaques; the secondary minerals are chlorite, sericite and epidote.

This gneiss forms persistent layers, up to 5 m in each thick-

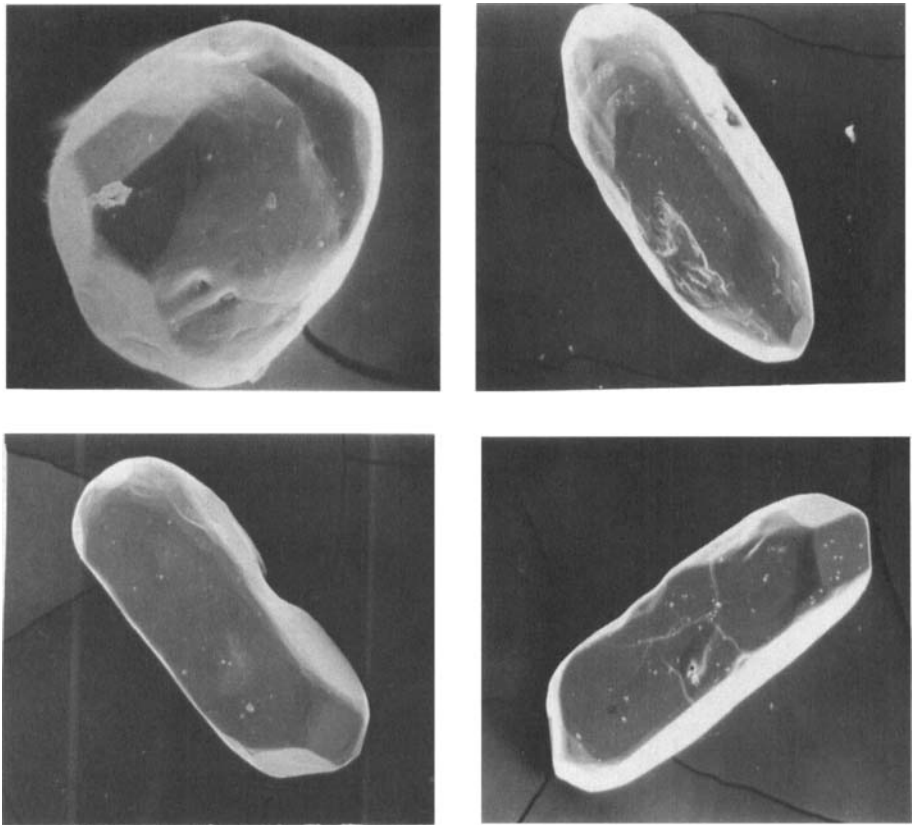

Fig. 2. Morphotypes of the zircon grains, scanning electro-micrographs. Upper left, morphotype 1, ×480, upper right, morphotype 1 × 168; lower left and lower right morphotype 2, both × 240.

Table 1. Lithostratigraphic schemes of Middle and Early Proterozoic successions in Ny Friesland, after Harland et al. (1985) and Krasil'ščikov (1973).

<table>
<tr><th colspan="3">Harland et al. 1966</th><th colspan="2">Krasilscikov 1973</th></tr>
<tr><td colspan="2">Planetfjellet Group</td><td rowspan="3">Stubendorffbreen Supergroup</td><td colspan="2">Mossel series</td></tr>
<tr><td>Sørbreen Fm.
Vassfaret Fm.
Bangenhuk Fm.
Rittervatnet Fm.
Polhem Fm.</td><td>Harkerbreen Group</td><td rowspan="2">Sørbreen Fm
Vassfaret Fm.
Bangenhuk Fm.
Rittervatnet Fm.
Harkerbreen Fm.

Smutsbreen Fm.
Eskolabreen Fm.</td><td rowspan="2">Atomfjella series</td></tr>
<tr><td>Smutsbreen Fm.
Eskolabreen Fm.</td><td>Finland veggen Group</td></tr>
</table>

Table 2. Isotopic analyses of U and Pb from the zircon fractions of the morphotype 1 from the Eskolabreen gneiss.

			U	Pb	Pb	ISOTOPIC RATIOS (measured)						ISOTOPIC RATIOS (corrected for blank and common Pb)						Age(Ma) (calculated)			
Lab no.	Size of fractions (μm)	Weight (mg)	ppm	radio genic ppm	common ppm	$^{206}Pb/^{204}Pb$	% err	$^{206}Pb/^{207}Pb$	% err	$^{206}Pb/^{208}Pb$	% err	$^{207}Pb/^{206}Pb$	% err	$^{207}Pb/^{235}U$	% err	$^{206}Pb/^{238}U$	% err	RHO	$^{207}Pb/^{206}Pb$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$
1	50-75	0.8	346	93.9	0.64	6009	4.6	7.386	0.10	7.058	0.14	0.1334	0.14	4.567	0.31	0.2483	0.27	0.897	2143	1743	1430
2	75-100	1.7	189	70.7	<0.001	7966	2.7	6.693	0.70	7.102	0.50	0.1480	0.71	6.888	0.76	0.3376	0.26	0.349	2323	2097	1875
3	>100	10.0	203	83.3	0.23	11318	3.8	6.662	0.20	6.107	0.30	0.1491	0.21	7.473	0.37	0.3634	0.30	0.819	2336	2170	1998
4	>100	8.6	156	65.6	0.52	6060	11.0	6.822	0.30	6.484	0.15	0.1446	0.35	7.524	0.45	0.3773	0.26	0.626	2283	2176	2064
5	< 50	0.9	294	64.7	30.50	121	0.7	4.216	0.22	2.454	0.44	0.1295	0.82	4.231	0.96	0.2369	0.35	0.556	2092	1680	1370
6	<100	0.6	327	101.4	1.02	4245	3.7	7.253	0.08	7.683	0.31	0.1350	0.13	5.340	0.28	0.2869	0.24	0.888	2164	1575	1626

ness, alternating with pink granitic gneisses and thin amphibolites of hornblende-biotite gneisses and is located about 100 m below the upper boundary of the Eskolabreen Formation in the core of the Atomfjella antiform. Many isoclinal fold hinges occur within layers and the gneissosities are all of tectonic-metamorphic in origin.

Zircons

Two morphotypes of zircon grains are distinguished in the rock (Fig. 2):

(1) Grains with facets of (111), (311), (110), (100) and wide bulging margins between them, having apparent oval or rounded outlines with the width/length ratios 1.5–2.5. They have smooth surfaces and are commonly transparent, yellow to brownish in colour. Some grains have thin overgrowths at the pinacles.

(2) Prismatic grains with (111) and (100) facets. These have relatively rough surfaces and the width/length ratios are 2–3.5. The colours are similar to morphotype 1, but darker and not as clear due to the rougher surfaces.

Zircons of both morphotypes have some inclusions of brown needles, probably thorite, and glass-liquid bubbles. The surfaces of grains do not show any abrasion pattern as usually seen on the surfaces of detrital grains. Thermal-ion mass-spectrometry studies on both types of zircon grains show a large difference in $^{207}Pb/^{206}Pb$ age (ca. 2.36 and 1.87 Ga), indicating at least two generations of the grains. The zircons of morphotype 2 have not been analysed in this preliminary study because they are considered to have a complex history of crystallization and would therefore give results difficult to interpretate.

Six size fractions of morphotype 1 zircon grains have been chosen for the present U/Pb analyses. Only transparent grains without overgrowth at the pinacles have been selected. Fraction 4 was air-abraded to remove the inner part and fraction 6 was additionally milled.

Isotope analyses and results

Extraction of U and Pb was performed by Krogh's (1973) method. After being washed with diluted nitric acid, the zircon grains were dissolved in 2 ml HF in teflon capsules and heated in aluminium bombs in an oven at 185°C for some days. After dissolution and aliquotation, the ID part was spiked with a mixed 235U-208Pb tracer. U and Pb were separated by ion-exchange using 6.2 M HCl and water. Total blank during the experiments were 0.05 ng for U and 0.1–0.5 ng for Pb.

The sample was loaded with nitric acid on a double Re filament for U and with silica gel and phosphoric acid on a single Re filament for Pb. Both were analysed with a MI-1201-T single collector mass spectrometer. The results of the measurements were corrected for blanks of 0.5 ng for Pb and 0.05 ng of U, and common lead using Stacey & Kramer's model (1975) for an age of 2,450 Ma.

The results of U and Pb isotope analyses are given in Table 2 and the obtained isochron is illustrated in Fig. 3. The four fractions define a discordia with an upper intercept of 2,415 + −34 Ma and a lower intercept of 624 + −68 Ma, with MSWD = 6.9. Two fractions, 4 and 6, are off from the discordia, probably due to later thermal effects and/or contamination during the air-abrasion for fraction 4.

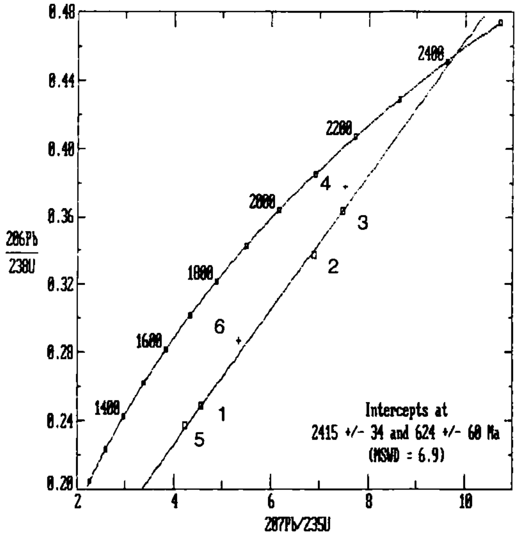

Fig. 3. U-Pb concordia diagram. Number of sample refers to Table 2.

Discussion

Close structural observations of the Stubendorffbreen Supergroup in this area show that all layered and banded structures in the rocks are of tectonic origin; no stratigraphic (sensu stricto) definition is therefore possible and the successions must be defined as lithostratigraphic of tectonostratigraphic units (Manby 1990; Gee et al. in press).

The protoliths of the rocks of the Harkerbreen and Finlandveggen Groups have been considered to be areno-argillaceous and arkosic sediments and bi-modal igneous rocks of mostly eruptive origin. The volcanigenic origin of some of these rocks has also been discussed by Manby (1990) and Sirotkin (unpubl. report). The latter author suggested a difference in a sedimentary environment for these groups, an extensional deep sea basin for the Finlandveggen Group and a transgressional shallow sea – subaerial basin for the Harkerbreen Group.

All previous authors agreed that these two groups belong to a large volcani-sedimentary succession without any orogenic break within it, though all observed contacts between the two groups are cut by thrust or steep fault in southern Ny Friesland.

The obtained U-Pb upper intercept age can be considered as a metamorphic zircon age, judging from the transparent colour, smooth surfaces lacking any trace of abrasion and the absence of any clearly zoned structure. This age is applicable to both the Eskolabreen and the Smutsbreen Formations, since these are conformable both in structure and metamorphism, but this age is not applicable to the Harkerbreen Group since this group is separated by faults from the Smutsbreen Formation in this area. This U-Pb upper intercept age suggests an older tectonothermal event than the emplacement of the Flåtan granite at ca. 1.7 Ga (Gee et al. 1992) in Ny Friesland. Similar ages of ca. 2.4–2.5 Ga have also been obtained recently from U-Pb upper intercepts of zircon from a quartz porphyryrhyolite clasts in a conglomerate-pyroclastic unit of the northwestern Hornsund (Balashov et al. 1992).

The Caledonian and Precambrian rocks of Ny Friesland have been compared with those of East Greenland (Harland 1985; Gee et al. 1992). There the 4–10 km thick Krummedal supracrustal sequence (Higgins 1988) has been metamorphosed during the Grenvillian period (e.g, Peucat et al. 1985), while much older U-Pb zircon upper intercept ages, ca. 1.9–3.0 Ga (Hansen & Friderichsen 1987; Hansen et al. 1987) and ca. 2.5 Ma (Peucat et al. 1985) have also been reported. However, these rocks are involved in complex gneiss-migmatite structures and the discrimination between Middle and Early Proterozoic rocks has not yet been completed.

The palinspastic position of Svalbard before Cenozoic ocean spreading is not too far from northern Ellesmere Island, and a structural unit of Caledonian affinity, Pearya, has been recognized in that area (Trettin 1987). Recent U-Pb zircon studies on the Caledonian and older rocks in Pearya yielded older ages than the Grenvillian, ca. 2.1 and ca. 2.2 Ga (Trettin et al. 1992). Both are considered to be from inherited zircons, but no geological constraints are known yet.

No correlative geological event has ever been observed in the present area which corresponds with the lower intercept age, ca. 625 Ma. But a few similar Rb-Sr and K-Ar ages are known in the northern parts of Nordaustlandet (Hamilton & Sandford 1964; Ohta 1992). A similar age for eclogitic metagabbroic rock has been obtained from Biskayerhalvøya (Peucat et al. 1989). This period corresponds to the time of the Baikalian event in the southeastern Barents Sea region; however, all these ages in Svalbard are from igneous rocks and no distinguishing structural event of this period has yet been recognized.

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