Radiometric and petrographic investigations of basement gneisses from well 7120/12-2, Troms I area, offshore northern Norway

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Core samples from the metamorphic basement from Troms I area, offshore northern Norway, consist of a fine-grained grey gneiss of granodioritic composition alternating with medium-grained granitic layers. Progressive deformation of the granitic layers produces an augen gneiss and eventually a banded blastomylonitic gneiss. The grade of metamorphism corresponds to amphibolite facies, but subsequent lower grade alteration with chloritization of biotite, sericitization of feldspar and carbonate veining has occasionally taken place.

Whole-rock isotopic analyses (Rb–Sr) give scattered data points which do not allow the calculations of a whole-rock age. However, the whole-rock data indicate a Precambrian age, as a model age of 1960 M.a. is obtained by assuming an initial $^{87}Sr/^{86}Sr$ ratio of 0.7050.

A Rb–Sr biotite - whole-rock age of 381 ± 7 M.a. agrees well with biotite ages from other segments of the Norwegian Caledonides. A K-fsp - whole-rock age of 553 ± 32 M.a. might indicate an early Caledonian (Finnmarkian) influence in the area.

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This note presents the first information obtained from the basement gneisses on the continental shelf outside northern Norway. The area is important as it represents a possible source region for the far travelled Caledonian thrust sheets encountered on land, and thus may provide the key to a better understanding of the tectonometamorphic evolution in this northern part of the Caledonides.

The type of material available so far does not allow us to draw far-reaching conclusions on the matter, but this note at least sheds the first ray of light into this vast unknown area.

The block 7120/12 is located about 130 km west of Hammerfest (Fig. 1).

Well 7120/12 was drilled in 1981. This is at present the only well off northern Norway where the metamorphic basement has been encountered. From this well 5.5 metres of basement with a diameter of ca. 12 cm have been cored and analysed.

Petrography and mineralogy

The core consists of a fine-grained grey gneiss of dioritic to granodioritic composition which alternates with bands, up to 15 cm thick, of light coloured, medium to coarse-grained, granitic material. The grey gneiss is approximately twice as abundant as the granitic gneiss.

The grey gneiss is strongly foliated (Fig. 2), the foliations being defined by parallel orientation of biotite, feldspar and quartz. The foliation has a shallow dip of 10–20°.

The typical grey gneiss is fine grained and carries the following minerals: ca. 35 modal % plagiochase (An_{25}), ca. 35 modal % quartz, 8–10 modal % biotite, ca. 10 modal % K-feldspar (microperthite) and 2–4 modal % of epidote. Accessories include sphene, apatite, zircon and muscovite. Epidote is strongly zoned with a marked core of pleochroic allanite mantled by a rim of epidote (Fig. 2).

In place, the light-coloured layers are nearly massive. However, varying degrees of deformation occur, and in the most extreme cases the light granitic material has been flattened to thin bands, thus producing a banded gneiss. These bands are locally thrown into intrafolial folds which bear witness of very great strain in the rock. Deformation of the light coloured material leads locally to the formation of an augen gneiss where coarse-grained aggregates of perthitic feldspar ($Or_{95}Ab_5$), quartz and plagioclase (An_{24})

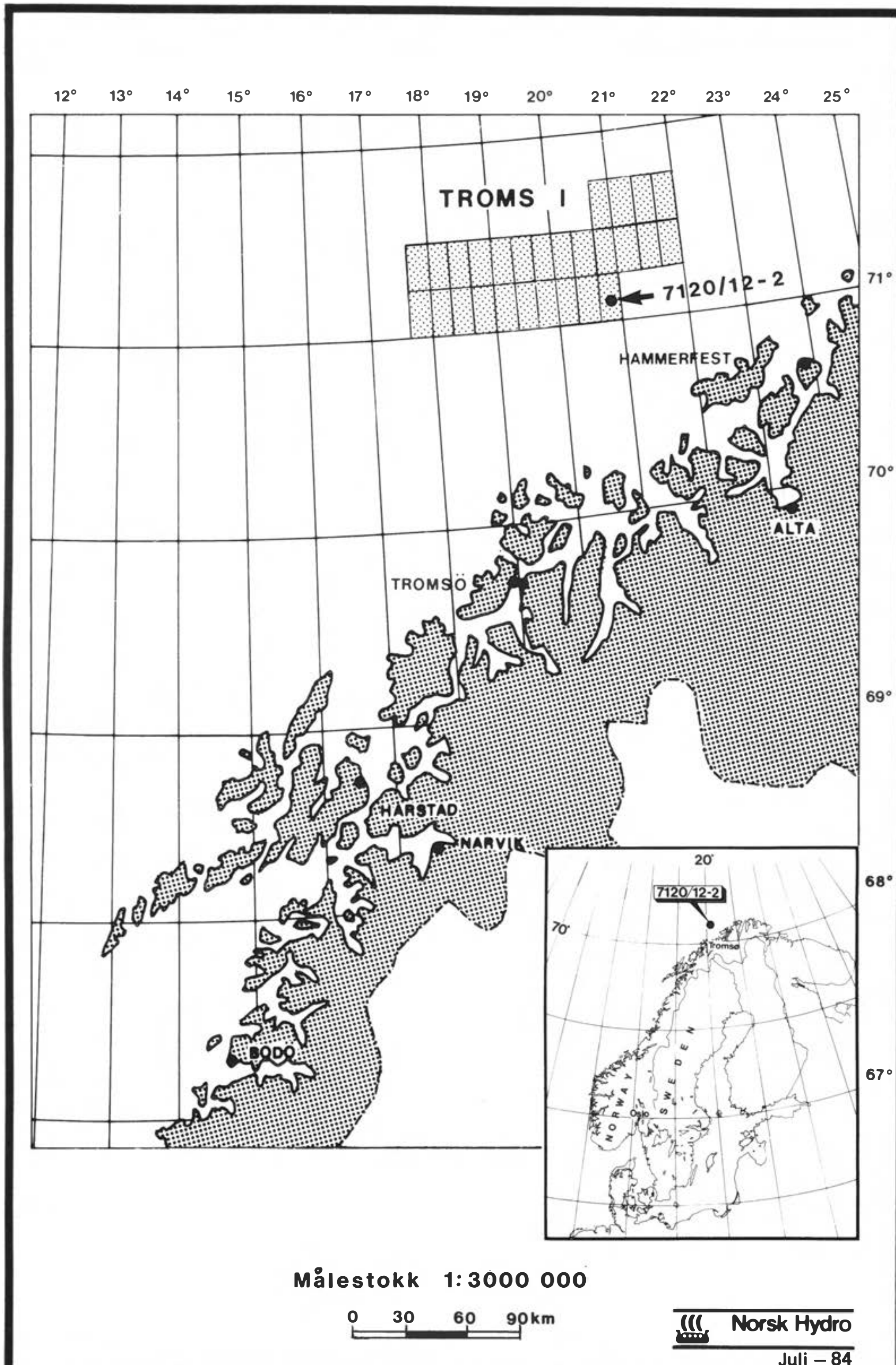

Fig. 1. Location map.

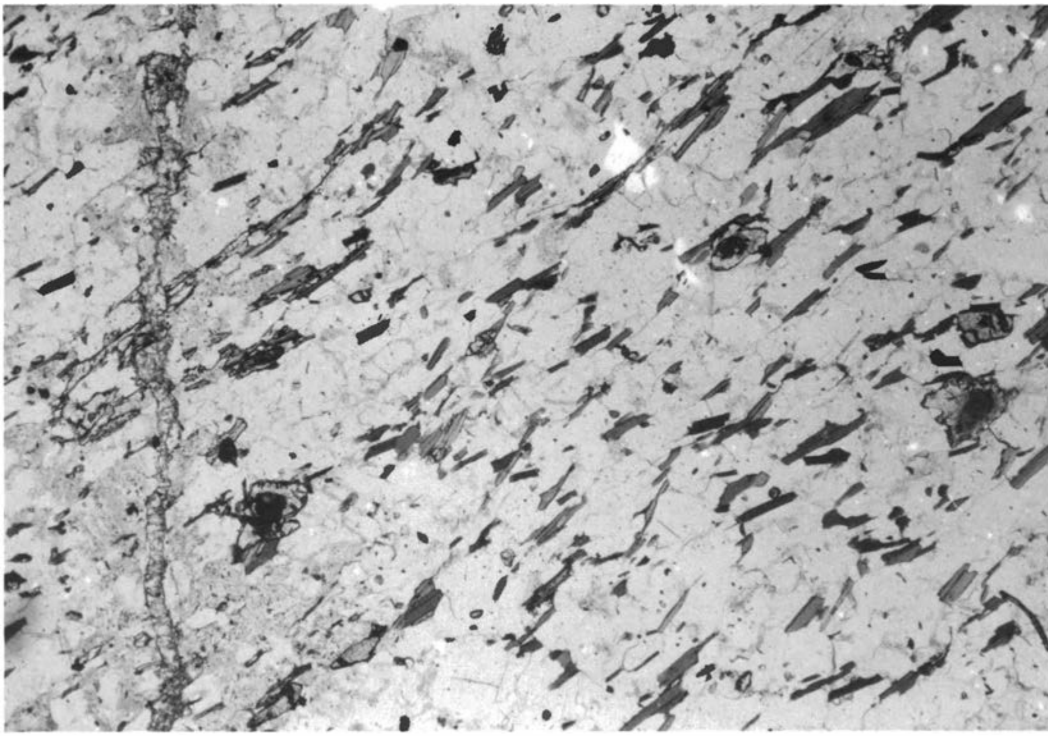

Fig. 2. Foliated grey gneiss from well 7120/12-2, Troms I area, northern Norway. Note the dark allanite cores in epidote. Abundant sericitization along the calcite filled vein (left hand side). Replacement of biotite by calcite in the vicinity of this vein. Sample NH1, width of photo: 2.5 mm.

float in a recrystallized matrix of plagioclase microcline and quartz. In addition to augen obviously formed by transposition of granitic layers, there are also augen up to one centimetre long that consist of one single crystal of weakly perthitic feldspar. These megacrysts are surrounded by well-developed myrmekites.

The medium-grained granitic bands consist of over 40 modal % of incipiently perthitic K-feldspar, about 20 modal % plagioclase, about 20 modal % quartz, muscovite and magnetite. The muscovite is often found in a corona texture surrounding magnetite. The An-content (> 20) of plagioclase in coexistence with epidote suggests that the mineral paragenesis of these gneisses equilibrated at amphibolite facies conditions. The lack of chlorite as part of this mineral assemblage supports this interpretation.

Alteration/retrogression. – The amphibolite facies mineralogy shows locally alteration and retrogression to a greenschist mineralogy. During this process, biotite is replaced by chlorite (brunsvigite) while plagioclase undergoes sericitization. The sericitization of plagioclase starts along grain boundaries and proceeds inwards, altering the plagioclase to phengite and albite (An_6), and possibly also clinozoisite. This sericitization process is therefore regarded as a metamorphic process, rather than being related to weathering. The grain size of the phengite, which reaches 0.2 mm in diameter, supports this.

Both rock types are fractured and the cracks are filled with calcite. In the vicinity of these cracks biotite/chlorite sometimes becomes replaced by carbonate. Whether this latter process is related to the sericitization or represents an even later event, cannot readily be decided, although the sericitization in places seems to be more intense along these cracks.

Isotopic analyses

Analytical procedure. – The rocks were crushed in a steel jaw-crusher and a split fraction was milled in a steel swing-mill to fine powder. Rubi-

Table 1. Analytical data for whole rock and minerals

Sample	Rb	Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr \pm 2\sigma$
NH1A	63.0	324.9	0.562	0.72402 ± 16
NH1B	57.7	315.6	0.530	0.72383 ± 14
NH6A	82.7	222.2	1.078	0.72398 ± 10
NH6B	79.6	205.9	1.119	0.72561 ± 8
NH8A	64.7	187.4	1.000	0.72724 ± 14
NH8B	77.0	181.9	1.227	0.73611 ± 14
NH9	60.4	261.4	0.669	0.72429 ± 14
NH10	57.6	346.6	0.481	0.72244 ± 14
NH10 Plag. I	10.7	311.5	0.100	0.72057 ± 16
NH10 Plag. II	19.4	354.5	0.158	0.72100 ± 16
NH10 K-fsp	163.4	465.5	1.018	0.72667 ± 10
NH10 Biotite	509.1	49.3	29.900	0.88207 ± 10
NH10 Epidote	55.6	699.4	0.230	0.71915 ± 8
NH11	60.1	347.9	0.501	0.72223 ± 10
NH12	63.3	347.9	0.527	0.72274 ± 10
NH13	69.7	325.0	0.623	0.72531 ± 16
Average (w. r.)	66.9	278.8	0.695	0.72462

ˣWeighed average of $^{87}Sr/^{86}Sr$ ratios

dium and strontium content of whole rock samples were determined by X-ray fluorescence, while the rubidium and strontium content of mineral fractions were determined by isotope dilution. Mass spectrometry was performed using a V6 Micromass 30 mass spectrometer at the Mineralogical Geological Museum in Oslo. Variable mass discrimination was corrected by normalizing the $^{87}Sr/^{86}Sr$ to 8.3752. The ^{87}Rb decay constant used was 1.42×10^{-11} per year. Regression lines were calculated using the technique of York (1969). In assigning errors to the regression points, the coefficient of variance for Rb/Sr is taken as 1 %. All errors quoted in this paper are two sigma errors.

Analytical results. – Nine whole-rock samples, weighing between 1 and 3 kg, were collected at approximately equal intervals along the available 5.5 m long core. The two largest samples NH6 and NH8 were further divided along the foliation into two parts and given subnumbers a and b. These eleven samples were analysed for Rb-Sr isotopes. The samples contained a number of cracks with calcite filling and alteration. These were removed as far as possible, but it was impossible to obtain samples completely free from these secondary features. The results are listed in Table 1 and plotted in Fig. 3.

The scatter of the datapoints (Fig. 3) indicate that the isotopic composition was disturbed, but not homogenized, during a subsequent geological event. In this case a model age can be calculated by assuming an I. R., providing that the system was closed on the 'locality' scale and that the mean Rb, Sr, $^{87}Sr/^{86}Sr$ calculated for the smaples (Table 1) is representative for the closed system. Model ages for the rock system calculated in this way give 1466 M.a. for an initial ratio of 0.7100 and 1960 M.a. for 0.705 (Fig. 3). A regression analysis of the grey gneiss alone and, excluding sample NH9, gives an age of 1731 ± 654 M.a. with a MSWD-value of 10.0 and a relatively high I.R. of 0.7100 of grey gneiss. Because of the limited spread in the Rb/Sr ratios of these samples, it is not possible to reduce the high uncertainty on this age.

Mineral dates. – Biotite, epidote, K-feldspar and two plagioclase fractions were separated from sample NH10 and analysed for Rb-Sr isotopes. Sample NH10 is typical grey gneiss which shows incipient alteration in the form of local chloritization of biotite and sericitization of plagioclase. The epidote contains allanite cores. The results are listed in Table 1 and plotted, together with the corresponding whole rock (w.r.), in Fig. 4.

The following ages have been calculated: biotite – w.r.: 381 ± 7 M.a., K-fsp. – w.r.: 553 ± 32 M.a., epidote – w.r.: 913 ± 60 M.a., plagioclase I – plagioclase II – w.r.: 334 ± 37 M.a.

The minerals clearly do not display isotopic equilibrium as might be expected from the petrographic description. Any interpretation of these results is therefore somewhat speculative.

The high $^{87}Rb/^{86}Sr$ ratio of biotite makes the

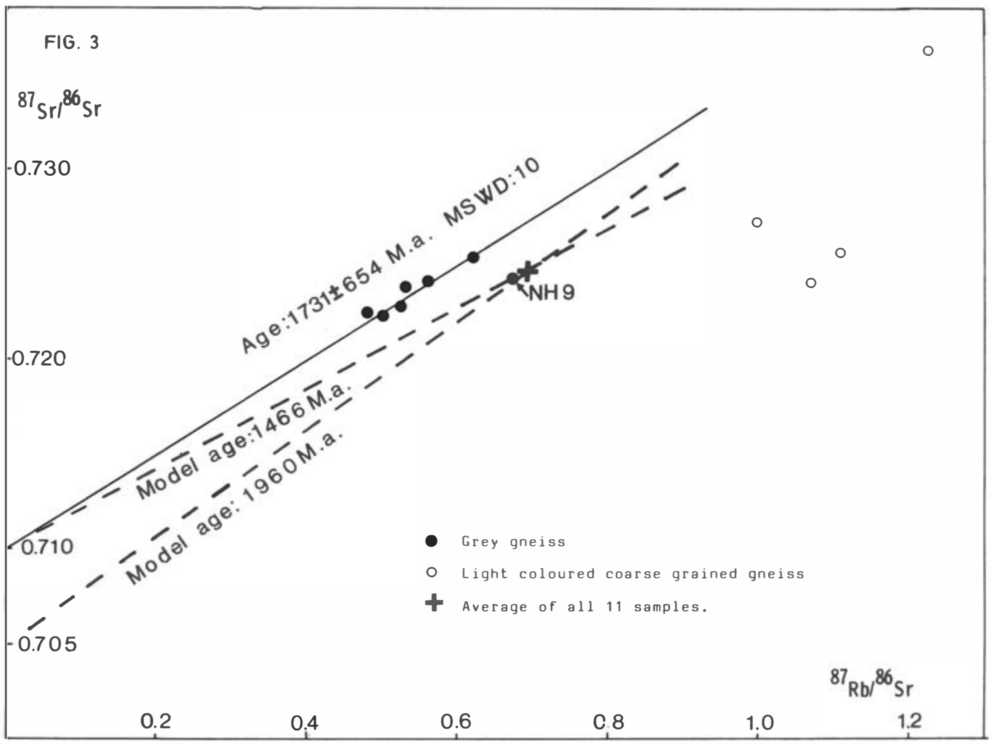

Fig. 3. Whole-rock Rb-Sr isochron diagram for basement gneisses from core 7120/12-2, Troms. The regression analyses giving an age of 1731 M. a. is based on the samples of grey gneiss excluding NH9,

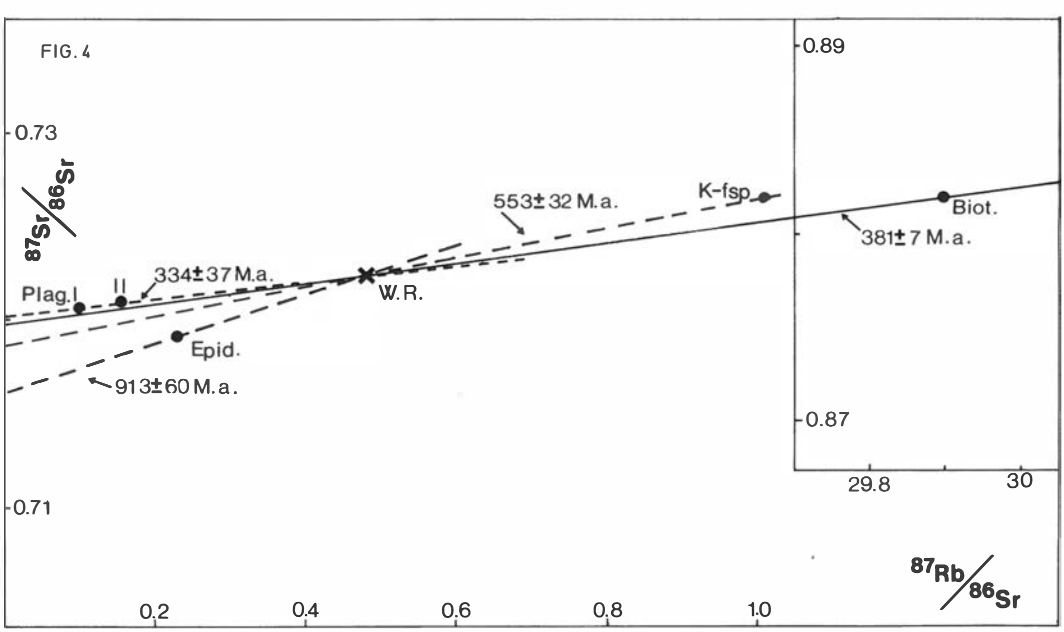

Fig. 4. Rb-Sr isochron diagram for minerals and corresponding w. r. for sample NH10. Epid.: Epidote. Biot.: Biotite. K-fsp.: K-feldspar. Plag. I and Plag. II: Plagioclase fractions I and II.

biotite – w.r. data less sensitive to a possible slight shift in the isotopic composition due to disequilibrium. The 381 ± 7 M.a. date can therefore be regarded as the isotopic age of biotite.

The other calculated mineral ages are more uncertain. They have less Rb-Sr spread and depend to a higher degree on correct positioning of the point in this diagram. In spite of this, the data suggest that the K-feldspar and epidote are distinctly older than the biotite.

Discussion and conclusions

The intense deformation and metamorphism of these rocks have wiped out all primary textures. However, the mineralogical composition, with abundant feldspar, points to a magmatic protolith of granodioritic composition for the grey gneiss. The granitic bands may have formed as a result of anatexis or they may have been intruded as granitic dykes.

The w.r. dating does not allow us to determine the exact protolith age of these gneisses. However, the data indicate a Precambrian origin. The biotite age of 381 ± 7 M.a. is in agreement with K-Ar biotite – w.r. ages obtained from basement gneisses, the Kalakk nappe (Sturt et al. 1978).

It is not certain whether this biotite age dates the amphibolite facies metamorphism or is the result of resetting due to chloritization during the retrograde event.

The Ksp – w.r. age of 553 ± 32 M.a. suggests that the amphibolite facies assembly was formed during the early Caledonian phase and that the biotite suffered a later resetting. The age of 913 ± 60 M.a. obtained from epidote – w.r. allows for the possibility that the allanite cores are part of an even older mineral assembly, although this could be a completely spurious age.

The radiometric data indicate that we are dealing with a rock complex which has undergone a complex metamorphic history. This conclusion is supported by the petrographic description which shows that the rock history involves mylonitisation at amphibolite facies conditions and subsequent greenschist facies alteration.

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References

Sturt, B. A., Bringle, I. R. & Ramsay, D. M. 1978: The Finnmarkian phase of the Caledonian Orogeny. *Geol. Soc. Lond., J1. 135*, 597–610.

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