Isotope Geochronology of the Eidfjord Granite, Hardangervidda, West Norway

H. N. A. PRIEM, N. A. I. M. BOELRIJK, E. H. HEBEDA,
E. A. TH. VERDURMEN & R. H. VERSCHURE

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The Eidfjord Granite has a 7-point whole-rock Rb–Sr isochron age of 931 ± 35 Ma with initial $^{87}Sr/^{86}Sr$ = 0.7058 ± 0.0028 (50.0 × 10^9 year ^{87}Rb half-life; errors at 95 per cent confidence level). Two separated biotites show the imprint of Caledonian metamorphism and post-orogenic cooling: Rb–Sr age 393 ± 7 Ma; K–Ar ages 405 ± 10 Ma and 432 ± 10 Ma, respectively.

H. N. A. Priem, N. A. I. M. Boelrijk, E. H. Hebeda, E. A. Th. Verdurmen & R. H. Verschure, Z.W.O. Laboratorium voor Isotopen–Geologie, De Boelelaan 1085, Amsterdam–11, The Netherlands

Introduction

It is generally understood that the rocks of Hardangervidda in the Caledonian belt of western Norway can be divided into three groups: a Precambrian basement, covered over large areas by an autochthonous/parautochthonous sequence of low-grade metamorphic Cambro-Ordovician sediments, which is again overlain by extensive thrust sheets of crystalline rocks (e.g., Strand 1972). In the Eidfjord area on the western edge of Hardangervidda the basement is composed of granitic gneisses and gneissose granites, intruded by a granitic mass designated here as the Eidfjord Granite (Fig. 1). To the east of Eidfjord, at Hardangerjøkulen, the topographically highest part of the region, the Cambro-Ordovician cover of the Precambrian basement is tectonically overlain by granitic gneisses (Barkey 1965) belonging to the Hardangervidda-Ryfylke Nappe System (Andresen et al. 1974).

A Rb-Sr isochron study was made of eight whole-rocks from the Eidfjord Granite. All samples are biotite or two-mica granites, showing effects of re-crystallization (newly formed biotite, stilpnomelane, sericitic aggregates, etc.). The sampling sites are plotted on Fig. 1. Biotite was separated from two samples and dated according to the Rb-Sr and K-Ar methods.

Experimental procedures and constants

Determination of the Rb and Sr contents and Rb/Sr ratios of the whole-rocks was made by X-ray fluorescence spectrometry. Strontium isotope ratios were normalized to $^{88}Sr/^{86}Sr = 8.3752$ and adjusted to $^{87}Sr/^{86}Sr = 0.7081$ in the Eimer & Amend $Sr(CO_3)_2$ standard. Analytical errors in Rb/Sr and $^{87}Sr/^{86}Sr$ are estimated to be within 2.0 and 0.4 per cent, respectively. For the biotites,

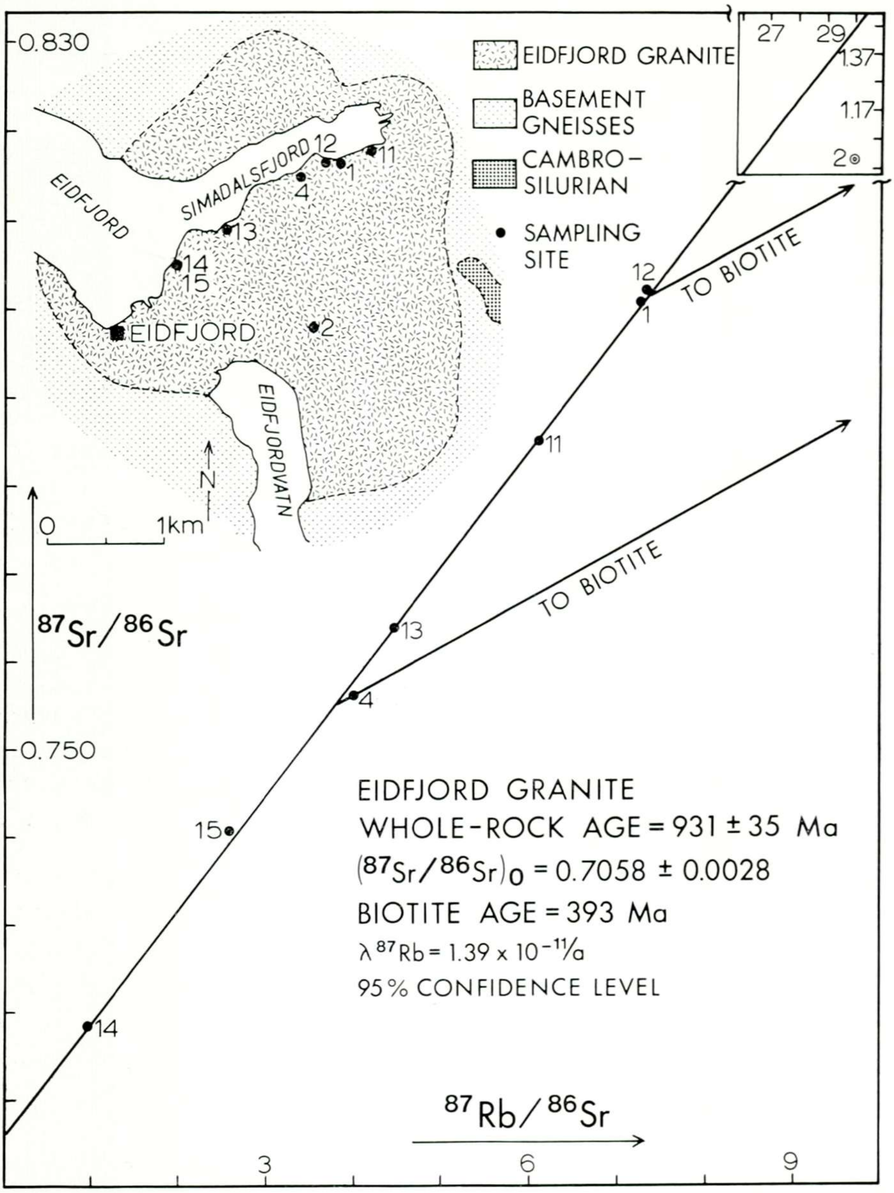

Fig. 1. Isochron plot of the samples from the Eidfjord Granite. The inset gives a geological sketch map of the area (after Barkey 1965), showing the locations of the investigated samples.

Rb and Sr were measured by isotope dilution techniques, while $^{87}Sr/^{86}Sr$ was calculated from the isotope dilution runs; the analytical errors are estimated to be within 2.0 per cent for Rb/Sr and within 0.5 per cent for $^{87}Sr/^{86}Sr$. Potassium determinations were made by flame photometry. Isotope dilution techniques were used to analyse the argon. For K and Ar the analytical errors are estimated to be within 1.0 and 2.0 per cent, respectively. The analytical

Table 1. Rb–Sr whole-rock data of the Eidfjord Granite

Sample No.	$^{87}Sr/^{86}Sr$*	Rb** (ppm Wt)	Sr** (ppm Wt)	Rb/Sr** (Wt/Wt)	$^{87}Rb/^{86}Sr$
66 Eid 1	0.8008	222	89.1	2.486	7.26
66 Eid 2	1.063	295	29.5	9.996	30.0
66 Eid 4	0.7558	196	143	1.367	3.98
72 Eid 11	0.7849	198	94.6	2.092	6.11
72 Eid 12	0.8019	226	90.5	2.499	7.31
72 Eid 13	0.7637	200	130	1.532	4.46
72 Eid 14	0.7185	179	541	0.3311	0.960
72 Eid 15	0.7405	231	260	0.8863	2.58

* Mean of duplicate analyses.

** X-ray fluorescence spectrometry (relative deviation ± 0.5%; estimated accuracy ± 1.5%). Mean of duplicate analyses.

procedures essentially follow those described by Priem et al. (1973b); only the X-ray fluorescence data were obtained in a different way, using a Philips PW1450/AHP automatic hardware programmed X-ray spectrometer equipped with a 3.0 kW Mo-target X-ray tube and a LiF (200) analysing crystal.

The ages mentioned in this paper are based upon the following constants:

$^{87}Rb : \lambda = 1.39 \times 10^{-11}/a$;
$^{40}K : \lambda_e = 5.85 \times 10^{-11}/a$;
$\lambda_\beta = 4.72 \times 10^{-10}/a$, and
abundance $^{40}K = 0.0118$ atom per cent total K.

Results and discussion

The analytical data of the Rb-Sr whole-rock analyses are listed in Table 1. When plotted in a diagram of $^{87}Sr/^{86}Sr$ versus $^{87}Rb/^{86}Sr$ (Fig. 1), seven whole-rocks show an excellent linear correlation and define an isochron of 931 ± 35 Ma with initial $^{87}Sr/^{86}Sr = 0.7058 \pm 0.0028$ (least-squares regression analysis according to York 1966, 1967; errors expressed at the 95 per cent confidence levels as calculated from the analytical data). All of these samples come from road-cut exposures at sea-level along the coast of Simadalsfjorden. The eigth sample (66 Eid 2) was taken about 1100 metres higher, at the plateau of Hardangervidda (Traelhaug); this sample falls below the regression line of the other seven samples and was omitted from the isochron calculation.

The seven-point whole-rock isochron of 931 ± 35 Ma can confidently be taken as the age of the Eidfjord Granite. The Rb-Sr system of the deviating sample 66 Eid 2 may have been disturbed by Caledonian overthrusting. This whole region is characterized by nappe structures (the 'Nappe region', cf. Strand 1972), so sample 66 Eid 2, coming from a much higher level in the Eidfjord Granite than the other seven samples, is situated much closer to the original overlying thrust plane (now removed by erosion).

Table 2. Rb–Sr data of biotites from the Eidfjord Granite

Sample No.	$^{87}Sr/^{86}Sr$*	Rb* (ppm Wt)	Sr* (ppm Wt)	Age** (Ma)
66 Eid 1	2.155	1321	17.0	390 ± 10
66 Eid 4	1.241	997	32.9	395 ± 10

* Isotope dilution. Mean of duplicate analyses.
** Calculated with reference to the corresponding whole-rock analyses.

Table 3. K–Ar data of biotites from the Eidfjord Granite

Sample No.	K* (% Wt)	radiogenic ^{40}Ar** (ppm Wt)	Age (Ma)
66 Eid 1	6.40	204×10^{-3}	405 ± 12
66 Eid 4	6.46	221×10^{-3}	432 ± 12

* Flame photometry. Mean of duplicate analyses.
** Mean of duplicate analyses. Atmospheric ^{40}Ar between 3% and 5% of the total ^{40}Ar.

In Tables 2 and 3 the Rb-Sr and K-Ar data of the two biotites from the Eidfjord Granite are listed. With reference to the appropriate whole-rock samples, the calculated Rb-Sr ages are 390±10 Ma and 395±10 Ma, respectively (Fig. 1). Within the error limits the K-Ar age of 66 Eid 1 is approximately concordant, but the K-Ar age of 66 Eid 4 (432±12 Ma) is significantly higher than the corresponding Rb-Sr age.

Th Rb-Sr isochron age of 931±35 Ma puts the emplacement of the Eidfjord Granite in Sveconorwegian time, contemporaneously with the intrusion of the late- to post-tectonic granitic plutons in southern Norway (e.g., Brueckner 1972, Priem et al. 1973b). Tectonothermal events in Caledonian time are reflected in the biotite ages. However, following Lambert's (1971) estimate of around 430 Ma as best approximation for the date of the Silurian/Devonian boundary (based upon $\lambda^{87}Rb = 1.39 \times 10^{-11}/a$), the mean biotite Rb-Sr age of 393±7 Ma falls well into the Devonian. This is a common feature of Rb-Sr and K-Ar ages of micas in the Norwegian Caledonides (e.g., Broch 1964, Sturt et al. 1967, Priem et al. 1967, 1968, 1973a, Brueckner 1972, Wilson 1972, Wilson & Nicholson 1973, Wilson et al. 1973). As the stratigraphical relationships denote a termination of the main Caledonian event in the central part of the mountain chain before the beginning of the Devonian (Strand 1972), such Devonian ages apparently fix the time during post-orogenic uplift and cooling at which the biotites became closed with regard to their Rb-Sr and K-Ar systems. The same holds for the lower of the two biotite K-Ar ages of the Eidfjord Granite, but the other age (432±10 Ma) could either date the termination of Caledonian metamorphism, or reflect an incomplete expulsion of radiogenic argon from the biotite in Caledonian time.

Preliminary investigations suggest that the basement gneisses into which the

Eidfjord Granite has intruded also have a Sveconorwegian age. Rb-Sr measurements on a single sample of granitic gneiss from the overthrust mass at the top of Hardangerjøkulen suggest an older age, of the same order of magnitude as the Rb-Sr whole-rock isochron age of 1643 ± 88 Ma measured by Andresen et al. (1974) on the Kvitenut Complex more to the south in the Hardangervidda–Ryfylke Nappe System. These studies will be continued.

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