Age Determinations from the Iveland-Evje Area, Aust-Agder

SVEND PEDERSEN

Pedersen, S. 1973: Age determinations from the Iveland–Evje area, Aust-Agder. *Norges geol. Unders. 300*, 33–39.

A Rb/Sr isochron age determination on intrusive granite and monzonite from the Iveland–Evje area gave an age of 1038 ± 43 m.y. Biotite from the granite dated by the K/Ar method gave an age of 845 ± 60 m.y. These values are very similar to other age determinations on intrusive rocks from Southern Norway.

The initial Sr^{87}/Sr^{86} ratio of the granite and monzonite is very low: 0.7048 ± 0.0003.

The rocks must be genetically related to the Iveland–Evje pegmatites, which are among the latest intrusions within the Sveconorwegian igneous period.

S. Pedersen, Institute of General Geology, Østervoldsgade 5, DK–1350 Copenhagen K, Denmark

Introduction

The paper describes some new age determinations from the Iveland–Evje area in Southern Norway. These were carried out on intrusive rocks, granite and monzonite, which had not previously been described. The method used was the Rb/Sr whole rock isochron method. One age, however, was obtained on biotite from granite by the K/Ar method.

The author mapped part of the Iveland–Evje amphibolite during the summers 1967 and 1968, with a final short stay in 1970; during the first field season the author was a member of the team working on the 'Telemark Project'. This mapping, being more detailed than that carried out by Barth (1947), revealed the granitic and monzonitic rocks.

Prior to the present study, all the age determinations from the Iveland–Evje area had been made on pegmatite minerals (Herr & Mertz 1958; Herr et al. 1958; Polkanov & Gerling in Neumann 1960; Kulp & Neumann 1961; Obrochev & Gerling in Broch 1964, and Herr & Wölfle 1967). Ages and methods are shown in Table 1.

Both Neumann and Broch remark that there is doubt about the significance of some of these ages. For instance, regarding the Re/Os determinations, the results suggest that the half-life of Re should be increased by about 20%. The Russian K/Ar determinations are 4 to 5% too high, because Russian geochronologists prefer the value $5.5 \times 10^{-11} yr^{-1}$ for the decay constant λ_ε, whereas the value $5.85 \times 10^{-11} yr^{-1}$ is normally used in other laboratories. From these early age determinations Neumann (1960) concluded that the pegmatites were emplaced 900–1000 m.y. ago.

Table 1. Previous age determinations from the Iveland–Evje area

Ref.	Method	Mineral	Age m.y.	Revised age m.y.	Locality
1.	RaD/Pb	Gadolinite	755		Frikstad
2.	Re/Os	Gadolinite	838		Frikstad
2.	Pb^{207}/Pb^{206}	Gadolinite	820		Frikstad
2.	RaD/Pb	Blomstrandine	884		Kåbuland
2.	Pb^{207}/Pb^{206}	Blomstrandine	920		Kåbuland
2.	Re/Os	Molybdenite	882		Tveit
2.	Re/Os	Molybdenite	962		Tuftan
3.	K/Ar	Biotite	880	835	Håverstad
4.	K/Ar	Muscovite	860		Iveland
5.	K/Ar	Biotite	1650	1582	Eptevann
5.	K/Ar	Biotite	1750	1679	Eptevann
6.	Re/Os	Molybdenite	1120		Tuftan
6.	?	Uraninite	1040		Tuftan

References:
1. Herr et al. (1958).
2. Herr & Mertz (1958).
3. Gerling & Polkanov in Neumann (1960).
4. Kulp & Neumann (1961).
5. Obruchev & Gerling in Broch (1964).
6. Herr & Wölfle (1967).

Outline of the geology in the northern part of the Iveland-Evje area

The Iveland–Evje area is famous for its nickel mineralisation (Vogt 1893, 1923; Bjørlykke 1947) and the many pegmatites carrying rare minerals (for general descriptions see Barth 1928, 1931, 1947; Andersen 1926, 1931; Bjørlykke 1934, 1937).

The nickel mineralisation and the pegmatites appear in an amphibolitic body described by Barth (1947) as the Iveland–Evje amphibolite. This body is 35 km in a north-south direction and its maximum width is 15 km.

Recent investigations by the present author (not yet published) have shown that, at least in the northern part, the Iveland–Evje amphibolite is made up of several bodies. One of these bodies, situated NE of Evje, is called here the Høvringsvatn Complex. It has a rather complicated structure; amphibolite is not the only rock type, contrary to what was previously thought. The complex consists of an older basic intrusion representing part of the Iveland–Evje amphibolite and a younger intermediate to acid intrusion of granite and monzonite. Some monzonitic rocks seem to be developed as thin cone sheets cutting amphibolite, granite, monzonite and the surrounding gneisses. Granite pegmatites and some aplites end this igneous activity.

It has to be emphasised here that the relations are very complicated, especially those between the granite and the cone sheets, as the granite has often been reactivated in connection with the intrusion of the sheets.

The Rb/Sr whole rock isochron age determinations described in the following were carried out on rocks from the Høvringsvatn Complex: granite

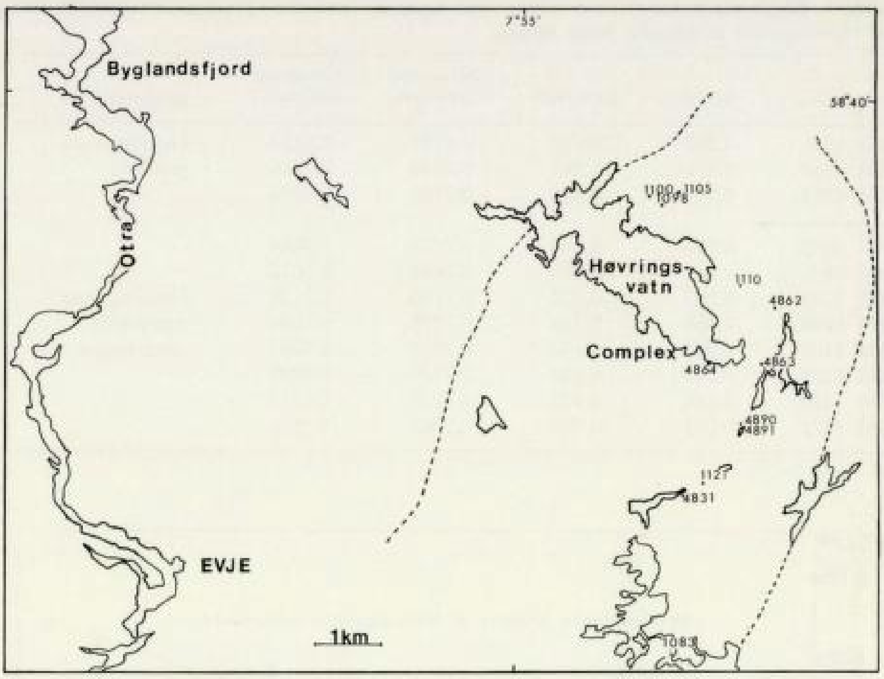

Fig. 1. Map of sample location.

(called Høvringsvatn granite), and monzonitic cone sheets (called Høvringsvatn monzonite). One K/Ar determination was carried out on biotite from the Høvringsvatn granite. The location of samples dated is shown in Fig. 1.

The Høvringsvatn granite is a medium- to coarse-grained rock, which is dominated by red, mainly euhedral potassium feldspar, and is characterised by a very homogeneous look and uniform grain size throughout the entire area.

Høvringsvatn monzonite embraces several structural types, all grey rocks carrying blue-green hornblende and green biotite as dark minerals and with a characteristic, marked content of abundant accessory sphene and apatite.

A thorough description of the rocks is planned in a later publication.

Rb/Sr age determinations and isotope analyses

Determination of Rb/Sr ratios: For the measurements of the ratio between Rb and Sr a Philips X-ray fluorescence apparatus with a W-tube (20 mA, 10 kV), an LiF 200 analysing crystal and a fine collimator were used. The peaks and background have been counted for 40 seconds.

The measurements were corrected for counter dead time, background curvature and peak interferences. These corrections have been described by Pankhurst (1968). All determinations were made in duplicate. The experimental error is in the range of 2% (1 σ level).

Table 2. Rb/Sr analytical data of whole rock samples from the Høvringsvatn granite and the Høvringsvatn monzonite (cone sheets)

Sample No.	Rb/Sr	Rb^{87}/Sr^{86}	Measured Sr^{87}/Sr^{86}	Corrected Sr^{87}/Sr^{86}	Rock type
MM 4831	0.302	0.874	0.7195	0.7183	Høvringsvatn
MM 4862	0.426	1.233	0.7230	0.7218	granite
MM 4864	0.119	0.345	0.7106	0.7094	
MM 4890	0.050	0.144	0.7076	0.7064	
MM 4891	0.061	0.175	0.7084	0.7072	
MM 1083	0.207	0.602	0.7140	0.7128	Høvringsvatn
MM 1098	0.086	0.248	0.7098	0.7086	monzonite
MM 1100	0.066	0.190	0.7079	0.7067	cone sheets
MM 1105	0.112	0.324	0.7109	0.7097	
MM 1110	0.146	0.425	0.7129	0.7117	
MM 1121	0.072	0.207	0.7088	0.7076	

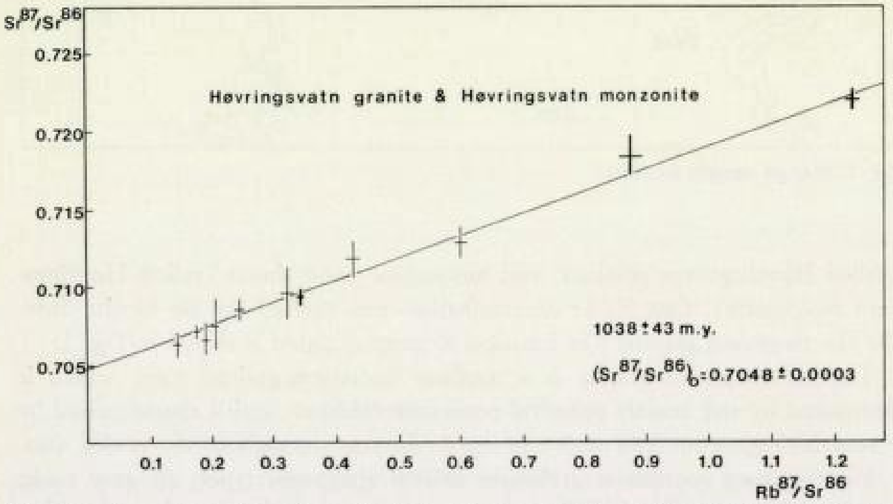

Fig. 2. Isochron plot for Høvringsvatn granite (heavy crosses) and Høvringsvatn monzonite cone sheets (light crosses).

Measurements of Sr isotope ratios: The chemical analyses were carried out at the dating laboratory of the Petrological Institute, University of Copenhagen, whereas the mass spectrometric investigations were undertaken on the Atlas CH–4 mass spectrometer at the Institute of Theoretical Meteorology, University of Copenhagen. A Faraday collector was attached to the mass spectrometer.

The Sr^{87}/Sr^{86} ratio obtained on the Eimer and Amend $SrCO_3$ standard (lot 492327) was 0.7092 ± 0.0004; all measured ratios were normalised to Sr^{86}/Sr^{88} values of 0.1194. The average obtained here is scarcely $2^0/_{00}$ higher than the normally accepted value of 0.7080, and for this reason just under $2^0/_{00}$ was subtracted from all the measured Sr^{87}/Sr^{86} ratios.

The experimental error varies between $0.5^0/_{00}$ and $2.5^0/_{00}$ ($1\ \sigma$ level).

Table 3. K/Ar analytical data of biotite from the Høvringsvatn granite

Sample No.	% K_2O	Ar^{40}_R/K^{40}	Age in m.y.
MM 4864 (Biotite)	9.4 ± 0.3	0.0627	845 ± 60

Results: All the values obtained (see Table 2) are plotted in the diagram Fig. 2. It is remarkable that these values, which represent both granite and monzonite, plot on a single isochron, giving an age of 1038 ± 43 m.y. with an initial Sr^{87}/Sr^{86} ratio of 0.7048 ± 0.0003. The decay constant used is $\lambda = 1.39 \times 10^{-11} yr^{-1}$ (Aldrich et al. 1956).

This isochron needs an explanation, as it contrasts with the field relations. In the field the monzonitic cone sheets are clearly seen to cut the granite; in places, however, the granite has been reactivated in connection with the monzonite intrusion. It may be either that the monzonite and granite are pene-contemporaneous and have a common initial ratio, or that the granite is older, but was reworked at the time of monzonite intrusion with the result that a resetting of the isotopic systems took place.

K/Ar determinations

K determinations: These were made on a Perkin Elmer 303 atomic absorption spectrometer. The samples were decomposed with the aid of hydrofluoric acid following a method described by Langmyhr & Paus (1968). The details of this method as used in the laboratory in Copenhagen have been described by Larsen (1971).

Ar determinations: The amount of radiogenic Ar was determined by isotope dilution on an AEI MS 10 mass spectrometer. A full description of this method has been given by Larsen & Møller (1968) and by Larsen (1971).

Results: The K/Ar determination was carried out on biotite from the Høvringsvatn granite. It gave an age of 845 ± 60 m.y. The results are shown in Table 3.

Concluding remarks

The Rb/Sr dating shows that intrusion of monzonite (and perhaps granite) took place about 1038 m.y. ago in the Iveland–Evje area.

There is a remarkable consistency between this age and the ages of the youngest intrusive, basic rocks of the Bamble area (1040 m.y., O'Nions et al. 1969) and the mangerites and farsundites of the Rogaland area (967 m.y. and 993 m.y. old respectively, according to Pasteels et al. 1970).

The earlier age determinations on pegmatite minerals showed that the pegmatites of the Iveland–Evje area are 900–1000 m.y. old (Neumann 1960) and consequently they must belong to the same intrusive period as the granite and monzonite. This period corresponds with the Sveconorwegian igneous period of Welin (1966).

The K/Ar age of 845 m.y. is in accordance with some of the earlier K/Ar determinations on pegmatite micas. Polkanov & Gerling (in Neumann 1960) obtained an age of 835 m.y. on biotite (converted age, see Table 1). Kulp & Neumann (1961) obtained 860 m.y. on muscovite from a pegmatite. On the other hand the results of Obruchev & Gerling (in Broch 1964), who obtained figures of 1582 m.y. and 1679 m.y. (converted ages, see Table 1), are not in agreement with these ages.

It is remarkable that K/Ar ages on biotite from the neighbouring Bamble area are higher than the result obtained here, i.e. about 970 m.y. (O'Nions et al. 1969).

Acknowledgements. – I wish to thank Professor A. Berthelsen, Dr. J. A. Dons and Professor H. Neumann for their help during the mapping and geological interpretation. I am also very much indebted to O. Larsen and J. Møller for help and criticism in connection with the experimental work. T. C. R. Pulvertaft kindly corrected the English.

REFERENCES

Aldrich, L. T., Wetherill, G. W., Tilton, G. R. & Davis, G. L. 1956: Half life of ^{87}Rb. *Phys. Rev. 103*, 1045–1047.

Andersen, O. 1926: Feldspat I. *Norges geol. Unders. 128a.*

Andersen, O. 1931: Feldspat II. *Norges geol. Unders. 128b.*

Barth, T. F. W. 1928: Zur Genesis der Pegmatite im Urgebirge. *N. Jahrb. f. Min.* etc., B. Bd. 58, Abt. A., 385–432.

Barth, T. F. W. 1931: Feldspat III. *Norges geol. Unders. 128b.*

Barth, T. F. W. 1947: The nickeliferous Iveland–Evje amphibolite and its relation. *Norges geol Unders. 168a.*

Bjørlykke, H. 1934: The mineral paragenesis of the granite pegmatites of Iveland, Setesdal, Southern Norway. *Norsk geol. Tidsskr. 14*, 211–309.

Bjørlykke, H. 1937: The granite pegmatites of Southern Norway. *J. Min. Soc. Am. 22*, No. 4, 241–255.

Bjørlykke, H. 1947: Flåt Nickel Mine. *Norges geol. Unders. 168b.*

Broch, O. A. 1964: Age determination of Norwegian minerals up to March, 1964. *Norges geol. Unders. 228*, 84–112.

Herr, W. & Mertz, E. 1958: Zur Bestimmung der Halbwertszeit des Re^{187}. *Z. Naturf. 13a*, 231–233.

Herr, W., Mertz, E., Eberhardt, P. & Signer, P. 1958: Zur Bestimmung der β–Halbwertszeit des Lu^{176} durch Nachweis von radiogenem Hf^{176}. *Z. Naturf. 13a*, 268–273.

Herr, W. & Wölfle, R. 1967: Development and recent applications of the Re/Os method. *Radioactive Dating and Methods of Low-level Counting, 499–508.* International Atomic Agency, Vienna 1967.

Kulp, J. L. & Neumann, H. 1961: Some potassium-argon ages on rocks from the Norwegian basement. *Am. N.Y. Acad. Sci. 91*, 469–475.

Langmyhr, F. J. & Paus, P. E. 1968: The analysis of inorganic siliceous materials by atomic absorption spectrophotometry and the hydrofluoric acid decomposition technique. Part 1: The analysis of silicate rocks. *Analytica chim. Acta 43*, 397–408.

Larsen, O. 1971: K/Ar age determinations from the Precambrian of Denmark. *Danmarks geol Unders. 11*, række nr. 97.

Larsen, O. & Møller, J. 1968: Radiometrisk datering af geologisk materiale efter kalium-argon metoden. *Fysisk Tidsskrift* 66. årgang nr. 1, 1–18.

Neumann, H. 1960: Apparent ages of Norwegian minerals and rocks. *Norsk geol. Tidsskr. 40*, 173–191.

O'Nions, R. K., Morton, R. D. & Baadsgaard, H. 1969: Potassium–argon ages from the Bamble section of the Fennoscandian Shield in South Norway. *Norsk geol. Tidsskr. 49*, 2, 171–190.

Pankhurst, R. J. 1968: Strontium isotope and geochronological studies of the basic igneous province of NE Scotland. Unpublished Ph. D. thesis.

Pasteels, P., Michot, J. & Lavreau, J. 1970: Le complexe éruptive du Rogaland Méridional (Norvège). Signification pétrogénétique de la Farsundite et de la mangerite quartzitique des unités orientales; arguments géochronologiques et isotopiques. *Annales de la Société Géologique de Belgique, Tome 93*, 453–476.

Vogt, J. H. L. 1893: Bildung von Erzlagerstätten durch Differentiationsprozesse in basischen Eruptivmagmata. *Z. Prakt. Geol.*, 4–11, 125–143 and 257–269.

Vogt, J. H. L. 1923: Nickel in igneous rocks. *Econ. Geol. 18*, 4, 307–353.

Welin, E. 1966: The absolute time scale and the classification of Precambrian rocks in Sweden. *Geol. Fören. Stockholm Förh. 88*, 29–33.