Rb-Sr study of dolerite dikes and psammite from the Western Gneiss Region of Norway

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The Sætra Nappe, consisting of feldspathic psammite cut by pre-tectonic dolerite dikes, is a distinctive tectonostratigraphic unit of the Western Gneiss Region of Norway. Although the rocks were metamorphosed at amphibolite facies, Rb-Sr whole-rock study of three well preserved dikes yields a date of 745 ± 37 Ma with initial $^{87}Sr/^{86}Sr$ = .7046, interpreted to record the dike intrusion. Analysis of small psammite samples collected in rows parallel to the foliation and in columns perpendicular to it, indicate that the Rb-Sr isotopic systems were not equilibrated on the whole-rock scale. The Sætra Nappe provides evidence of a strong Caledonian deformation/metamorphic event in the Western Gneiss Region of Norway.

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The Western Gneiss Region includes the unfossiliferous medium- to high-grade schists and gneisses that form a large part of Western Norway. The region was long considered to represent the orogenic core of the Scandinavian Caledonides (Wegmann 1935; Holtedahl 1953; Strand 1961), and the gneisses thought to include Precambrian basement and Eocambrian-Paleozoic cover rocks, both largely transformed by Caledonian granitization. These interpretations were supported by early geochronological studies, as minerals consistently yielded Caledonian dates (Broch 1964). However, recent whole-rock Rb-Sr age determinations have necessitated re-evaluations of earlier conclusions. Many gneisses have yielded Precambrian isochrons, showing that they were not formed by Caledonian granitization. Thus, it has become uncertain which, if any, of the rocks, structures, and metamorphic assemblages are of Caledonian age. Many recent geochronologic studies, geologic studies, and regional reviews have suggested that the last major orogenic event in the Western Gneiss Region was Precambrian, and that Caledonian orogenesis may involve only relatively brittle deformation and low-grade metamorphism (e.g. Råheim 1977; Skjerlie & Pringle 1978; Krogh 1977; Bryhni & Brastad 1980; Roberts & Sturt 1980).

However, these conclusions are based largely on interpretations of the meaning of Rb-Sr whole-rock dates, which are potentially equivocal as a result of geologic and isotopic complexities (Krill & Griffin 1981). This paper addresses two problems that previously have hindered interpretations of Rb-Sr results in the Western Gneiss Region.

(1) Intrusive rocks with well defined field relationships are scarce, and the few dates obtained have not helped to bracket the orogenic events. 'Late'- and 'post'-tectonic intrusive rocks have given Caledonian dates (Pidgeon & Råheim 1972; Ilebekk 1981) but none have given Precambrian dates, which would be clear evidence of a strictly limited degree of Caledonian metamorphism. Conversely, some 'pre'- and 'syn'-tectonic intrusions have given Precambrian dates (Priem et al. 1973; Brueckner 1979; Råheim 1979) but none have given Caledonian dates, which would clearly demonstrate that the Caledonian orogenesis played a major role here. The dolerite dikes examined in the present study are an example of the latter.

(2) The data points on Rb-Sr diagrams are almost invariably scattered and the scattering is difficult to interpret. Although some rocks in the Western Gneiss Region have yielded Precambrian isochrons, many schists and gneisses, especially those earlier presumed to be Caledonian, do not record isochrons, but rather 'errorchrons' with scatter of the data points about Precambrian or Caledonian reference lines. If the scatter is interpreted as being secondary (caused by retrogression, late cleavage, or jointing) the errorchrons are considered to represent minimum meta-

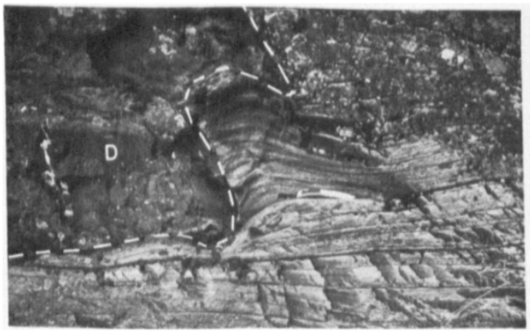

Fig. 1. Stepped dolerite dike (D) cutting sedimentary layering. Knife is 20 cm long.

Fig. 2. Isoclinal fold in psammite, developed adjacent to strongly deformed metadolerite. Hammer is 50 cm long.

morphic ages (Råheim 1977; Solheim 1980). Alternatively, if the scatter reflects incomplete isotopic equilibration during metamorphism, the errorchron dates could be maximum ages for the metamorphism. Feldspathic psammites that produced strongly scattered data (Solheim 1980) are reexamined in the present study in an attempt to interpret this scatter.

Geologic setting

The eastern margin of the Western Gneiss Region, near the Trondheim Region, is generally less deformed and metamorphosed than western parts, and a tectonostratigraphy and structural history are resolvable (Krill 1980a). The Sætra Nappe, consisting of feldspathic psammite cut by dolerite dikes (Bjørlykke 1905; photo p. 389), is a distinctive and areally extensive tectonostratigraphic unit. Regional correlations suggest that the Sætra Nappe is a western extension of the Särv Nappe, and local field relationships indicate that the dolerite dikes intruded before the large-scale thrusting of the Sætra Nappe and metamorphism and recumbent folding of the tectonostratigraphy (Krill 1980a). The samples of metadolerite and feldspathic psammite discussed here were all collected from the Engan flagstone quarries near 'Sætra' south of Oppdal (map Fig. 1, Krill 1980a). The quarries provide excellent exposure in a thick and relatively well preserved part of the Sætra Nappe.

Table 1. General characteristics of Sætra dikes.

	Weakly deformed	Intensely deformed
Thickness	1–5 metres	0–10 cm
Orientation	Subvertical, cutting bedding in psammite at high angles (Fig. 1)	Subhorizontal parallel to tectonic layering in psammite
Structure	Competent dikes or boudins. Psammite folds form adjacent dikes (Fig. 2)	Sheared, or isoclinically folded and interlayered with psammite (Fig. 2)
Texture	Massive, unfoliated igneous texture (Fig. 3). Some dikes porphyritic with chilled margins	Strongly foliated schist (Fig. 4)
Mineralogy	Hbl, plag, qtz, (relict-)cpx, opaque, epid, zois, ±gar	Biot, epid, qtz, ±opaque, ±K-spar, (hbl, plag, absent)

Dolerite dikes

The degree of deformation is variable and nearly all of the characteristics of the dikes (thickness, orientation, structure, texture, mineralogy, and chemistry) vary with the degree of deformation (Figs. 1–2). Table 1 summarizes general characteristics of the least deformed and most deformed dikes. However, all intermediate stages of deformation are found, and individual dikes can be traced from weakly to intensely deformed parts.

Samples of unfoliated metadolerite were collected from three of the least deformed dikes. Locations of the dikes, petrographic descriptions of samples, and analytical techniques are presented in the Appendix. Samples from dikes 'M' and 'D' contained no weathered surfaces, and five samples of each were analysed. Only two samples were analysed from dike 'A', which contains rusty-weathered joints and traces of meta-

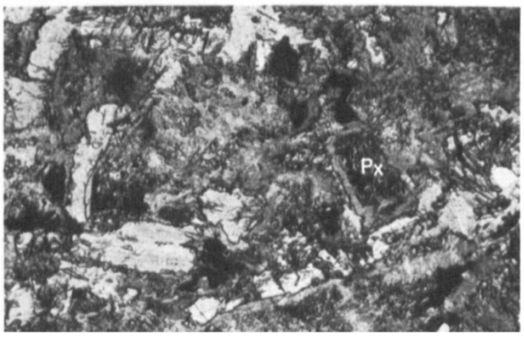

Fig. 3. Unfoliated metadolerite of dike 'M'. Pyroxene (Px) is largely replaced by amphibole. Photomicrograph is 1.3 mm long. Plane light.

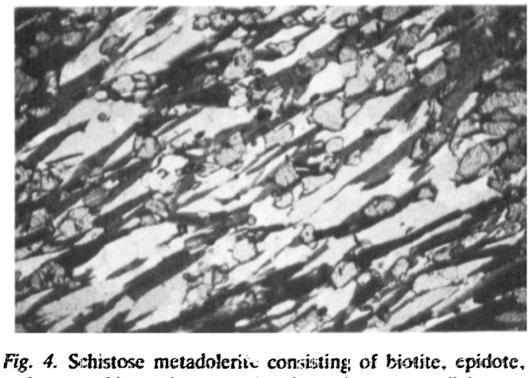

Fig. 4. Schistose metadolerite consisting of biotite, epidote, and quartz. Photomicrograph is 3.2 mm long. Plane light.

morphic biotite. In addition, a sample of biotite-epidote schist from the intensely deformed part of a fourth dike was analysed (Fig. 4). Analyses of major and trace elements are listed in Table 2. The dolerite samples have chemical characteristics typical of abyssal or oceanic tholeiitic basalt, and are very similar to the Ottfjället dolerites of the Särv Nappe (Solyom et al. 1979) and those occurring in the upper part of the Leksdal Nappe (Andreasson et al. 1979).

Whole-rock Rb-Sr results on the twelve samples from dikes M, D, and A are listed in Table 3 and plotted in Fig. 5. Although the Rb/Sr ratios are very low, there is sufficient dispersion to define an isochron corresponding to an age of 745 ± 37 Ma, $(^{87}Sr/^{86}Sr)_0 = .7046 \pm .0003$, MSWD = 1.1. Sample 67A has several rusty joint surfaces and was not included in the regression. Inclusion of this sample does not significantly change the date, but raises the MSWD value to 7.7.

Dikes M and D each have enough spread in Rb/Sr ratios to yield separate whole-rock dates. The five samples of dike M produce a well defined isochron date of 738 ± 56 Ma, $(^{87}Sr/^{86}Sr)_0 = .7046$, MSWD = 0.4. Dike D is chemically less variable, and the date has larger uncertainty: 635 ± 231 Ma, $(^{87}Sr/^{86}Sr)_0 = .7050$, MSWD = 0.7.

The dates are interpreted as the age of igneous intrusion. The extremely low ratios of $^{87}Sr/^{86}Sr$ are in the range typical for isotopically unaltered basalt (Faure & Powell 1972; Carmichael et al. 1975). The initial $^{87}Sr/^{86}Sr$ ratio of the dolerite (.7046) is within the range of mantle-derived values (Faure & Powell 1972). The initial ratio is higher than most modern mid-ocean ridge basalts, but lower than most tholeiitic basalts within continental rocks (Carmichael et al. 1975). This low ratio suggests that these samples of dolerite were not significantly contaminated by Sr from the psammite or other rocks during the generation, intrusion, or metamorphism of the dolerite.

In contrast, the sample of strongly foliated biotite-epidote schist from the fourth dike contains relatively large amounts of K and Rb, and very little Na, compared to unfoliated samples (Table 2). Although it gained Rb and Sr from the psammite, the Rb-Sr analysis plots below the 745 Ma isochron line (Fig. 6), whereas analyses of psammite (Fig. 6 and Solheim 1980) plot above the line. Thus, in this particular metadolerite sample the gain in ^{87}Rb was qualitatively more significant than the gain in ^{87}Sr.

Table 2. Chemical analyses of Sætra metadolerites.

	Unfoliated				Schistose
	M N = 5	D N = 5	A N = 2	Average N = 3	204 N = 1
SiO_2	50.96	51.02	51.90	51.29	51.26
TiO_2	1.50	2.35	1.66	1.84	2.27
Al_2O_3	14.55	12.59	14.20	13.78	12.96
Fe_2O_3	11.38	15.91	11.31	12.87	13.61
MnO	.18	.25	.20	.21	.20
MgO	7.14	4.74	6.68	6.19	5.06
CaO	10.96	9.17	10.54	10.22	8.03
Na_2O	1.96	2.08	2.07	2.04	.03
K_2O	.34	.51	.48	.44	3.63
P_2O_5	.15	.26	.18	.20	.28
Rb (ppm)	10	15	14	13	133
Sr	197	155	230	194	260
Zr	86	131	107	108	–
Nb	5	9	7	7	–
Y	23	44	25	31	–

Table 3. Rb-Sr analyses.

Samp. No.	Wt. (kg)	Rb (ppm)	Sr (ppm)	87Rb/86Sr	87Sr/86Sr	1-sigma Error
Metadolerite						
66A	1.4	14.46	231.2	.181	.70667	.00007
67A	1.6	15.69	229.6	.173	.70700	.00006
68M	2.0	6.73	194.0	.100	.70556	.00018
69D	1.5	16.11	157.9	.295	.70775	.00005
70D	2.2	14.21	155.5	.264	.70742	.00006
71M	2.4	9.85	195.6	.146	.70608	.00004
72M	2.4	7.95	202.1	.114	.70572	.00008
73D	2.2	16.80	157.4	.309	.70780	.00005
74D	3.7	14.42	155.2	.268	.70752	.00008
75M	4.7	4.86	207.6	.068	.70534	.00007
76M	2.0	19.59	189.0	.300	.70775	.00006
77D	3.9	13.66	152.3	.259	.70728	.00012
204	.44	132.9	259.9	1.48	.71661	.00006
Psammite						
42	1.5	169.1	189.2	2.59	.74055	.00007
43	1.2	165.1	186.5	2.57	.73986	.00008
44	1.2	170.4	181.2	2.72	.74103	.00006
45	1.0	166.6	170.0	2.69	.74199	.00006
46	.99	148.5	188.6	2.29	.74068	.00014
47	.52	148.6	168.8	2.56	.74386	.00010
48	.75	149.8	146.2	2.98	.74459	.00008
49	1.1	166.3	189.9	2.54	.74034	.00009
50	1.3	170.1	183.6	2.69	.74197	.00007
51	1.1	166.8	181.9	2.66	.74039	.00008
52	1.0	98.56	287.8	.993	.72861	.00003
53	.80	174.1	215.9	2.34	.74057	.00013
54	.78	154.5	170.5	2.63	.74383	.00006
126	1.4	92.82	295.3	.911	.72799	.00006
127	1.3	104.3	293.6	1.03	.72902	.00005
128	1.5	95.84	296.9	.929	.72819	.00010
129	1.6	98.24	290.4	.981	.72872	.00007
130	.52	175.0	199.9	2.54	.74338	.00010
131	.46	112.5	148.9	2.20	.74170	.00007
132	.44	151.6	154.7	2.84	.74441	.00009
133	.54	185.3	189.2	2.84	.74321	.00006
134	.50	131.3	142.0	2.68	.74404	.00005
135	.59	170.4	163.2	3.03	.74455	.00009
136	.71	132.2	179.0	2.14	.74075	.00007
137	.60	130.7	148.0	2.56	.74225	.00009
138	.34	186.2	140.6	3.84	.74785	.00009
139	.55	132.8	136.4	2.83	.74427	.00007
140	.52	160.8	162.3	2.88	.74288	.00008

Such isotopic disturbance is presumably controlled by the composition of the adjacent psammite and by the extent of local metasomatic exchange of ^{87}Rb and ^{87}Sr. The 745 Ma isochron line could be produced by such isotopic disturbance only if: (a) The three dikes initially had no spread in Rb-Sr ratios, and (b) ^{87}Rb and ^{87}Sr were added in the same proportion to samples in each dike. This proportion could not have been the same as the average ^{87}Rb/^{87}Sr ratio of the psammite, as the 745 Ma isochron line is clearly not a mixing line between dolerite and psammite. Thus, it seems unlikely that the isochron resulted from isotopic exchange with the psammite. If the dolerite isotopic ratios had been reset by secondary equilibration independent of the surrounding psammite, the different dikes would produce parallel isochrons with dike D defining a higher initial ^{87}Sr/^{86}Sr ratio than dike M. The only simple interpretation of the present iso-

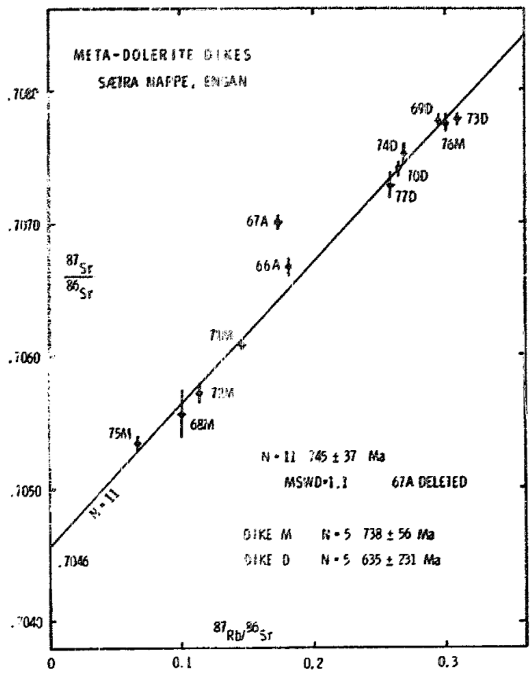

Fig. 5. Rb-Sr plot. Unfoliated metadolerite.

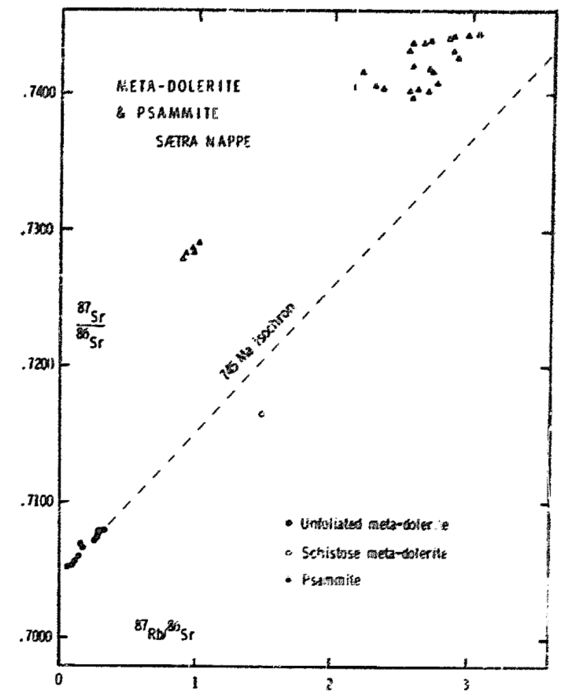

Fig. 6. Rb-Sr plot. All samples.

chron is that the $^{87}Sr/^{86}Sr$ ratio was homogeneous in the original source magma of the three dikes, and that the isochron records the age of this homogenization.

During metamorphism, H_2O must have entered even the unfoliated metadolerite, to produce hornblende and epidote in the originally anhydrous dolerite. However, this migration of fluid was not accompanied by significant disturbance of the major or trace-element chemistry, or by exchange of Sr or Rb isotopes between the psammite and dikes M and D. Thus, it may not be assumed that fluid migration automatically resets the whole-rock date.

The Ottfjället dolerite dikes of the Särv Nappe in Sweden have yielded a whole-rock Rb-Sr isochron age 720 ± 255 Ma, $(^{87}Sr/^{86}Sr)_0 = .7036 \pm .0005$ ($\lambda = 1.42 \times 10^{-11}$, Claesson 1976). The interpretation of this isochron as the intrusive age (Claesson 1976) is supported by the present results and the strong petrographic and structural similarities between the Särv and Sætra Nappes. Prost et al. (1977) considered the Ottfjället dikes to be much older on the basis of K-Ar dates ranging between about 600 Ma and 2500 Ma (Point et al. 1976, 1977). However, the Sætra date of 745 ± 37 Ma supports the interpretation that the older K-Ar dates resulted from excess Ar (Claesson 1977).

Feldspathic psammite

The Sætra psammite is a light grey to white fluvial sandstone, metamorphosed to amphibolite facies together with the enclosed dolerite dikes. The general petrography of the psammite was described by Barth (1939) and the regional setting by Krill (1980b). The samples for the present study consisted of 40–55% quartz, 15–20% K-feldspar, 10–15% plagioclase, 5–20% muscovite, 1–5% epidote, and 1–5% hematite.

The degree of deformation of the psammite is variable. Although strain is generally very intense, cross beds are well preserved in several parts of the flagstone quarry area, and the transition from irregularly bedded sandstone to well foliated flagstone can readily be observed. The cross beds are progressively sheared and flattened into the tectonic layering. Original mineralogical and color features of the rock, as well as the cross beds, were flattened and mechanically drawn out into parallel layers. The average color and mineral composition within layers are

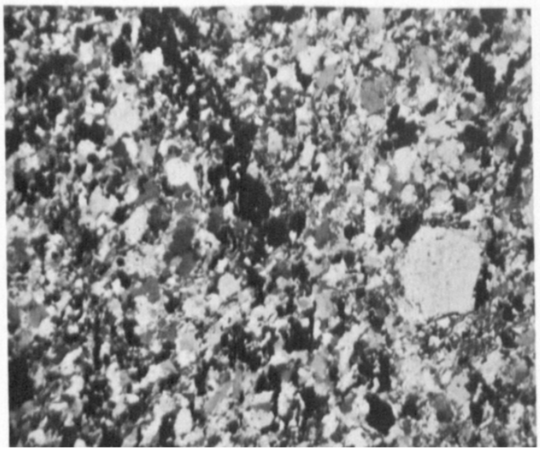

Fig. 7. Undeformed psammite. Photomicrograph is 8 mm long. Parallel-polarized light.

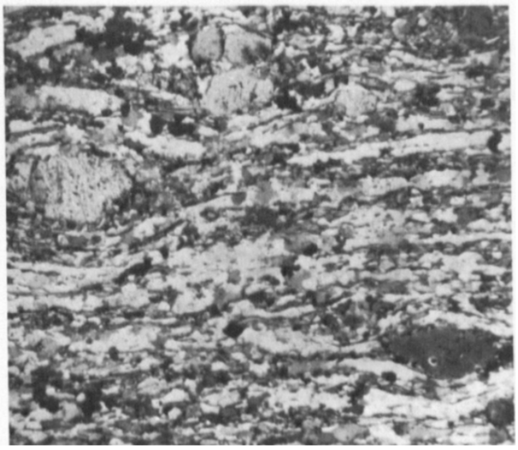

Fig. 8. Deformed psammite flagstone (Sample 52). Photomicrograph is 8 mm long. Parallel-polarized light.

similar, but there is generally no zoning of mineral assemblages or systematic color changes across layers. There is no indication that metamorphic differentiation or chemical migration were significant except near the dolerite dikes and local epidote-rich layers. Thin-sections of the cross-bedded psammite show that sedimentary grains of K-feldspar and quartz are of similar size (Fig. 7). In the strongly foliated flagstone, however, the quartz is strained and elongate, or recrystallized to smaller grains. The K-feldspar grains remain as relatively large porphyroclasts (Fig. 8), suggesting that the foliation is partly cataclastic. Foliation in the quarried flagstone is remarkably regular, allowing for easy splitting of samples from adjacent layers. Indeed, skilled quarrymen can split thin slabs, 5–10 mm thick and over a meter on each side, from arbitrarily selected positions in a thick psammite block. The splitting properties of the psammitic flagstone were useful for the present Rb-Sr study.

A previous Rb-Sr whole-rock study of foliated psammite from the Western Gneiss Region (Solheim 1980) showed the difficulty of carrying out routine Rb-Sr whole-rock dating of this rock type. One of the four suites studied gave a six-point isochron of 1035 ± 94 Ma, $(^{87}Sr/^{86}Sr)_0$ = = 7110, with the seventh point deleted. The other three suites gave only very scattered points on the Rb-Sr plots and no possible dates. It was suggested that the main metamorphism was of Svecofennian age (c. 1800 Ma), and that a crenulation cleavage of Sveconorwegian age (c. 1000 Ma) disturbed or reset all the samples, producing the 1035 Ma isochron. This cleavage, or a younger geological disturbance, was thought to have produced the scattered values of the other samples.

The present study was made to help deduce the meaning of the scatter. A single fresh block of very strongly foliated and lineated flagstone was carefully broken into samples of similar size and specific orientation (Fig. 9a). Samples were broken perpendicular to the foliation (seven samples of column A), and within the foliation parallel to the lineation (seven samples of row B and five samples of row C). The samples from column A plot in a very scattered colinear array (black dots, Fig. 9a). The samples from rows C and B plot in two distinct clusters with very little scatter within each cluster (open circles, Fig. 9a). These results indicate that the isotopic values are not randomly scattered, and that the position of points on the Rb-Sr plot are related to the main fabric (foliation or lineation). Secondary features at high angles to the foliation, such as joint surfaces or crenulation cleavages, cannot be responsible for scatter of the points, since such features would tend to equilibrate samples across the fabric rather than parallel to it, and the columns of samples should therefore show less scatter than the rows.

The flagstone is layered with respect to Rb-Sr isotopic ratios, just as it is layered mineralogically. The Rb-Sr results suggest that the Rb and Sr isotopes were largely mechanically transported with the mineral grains during formation of the present tectonic layering. Consequently the ^{87}Sr/

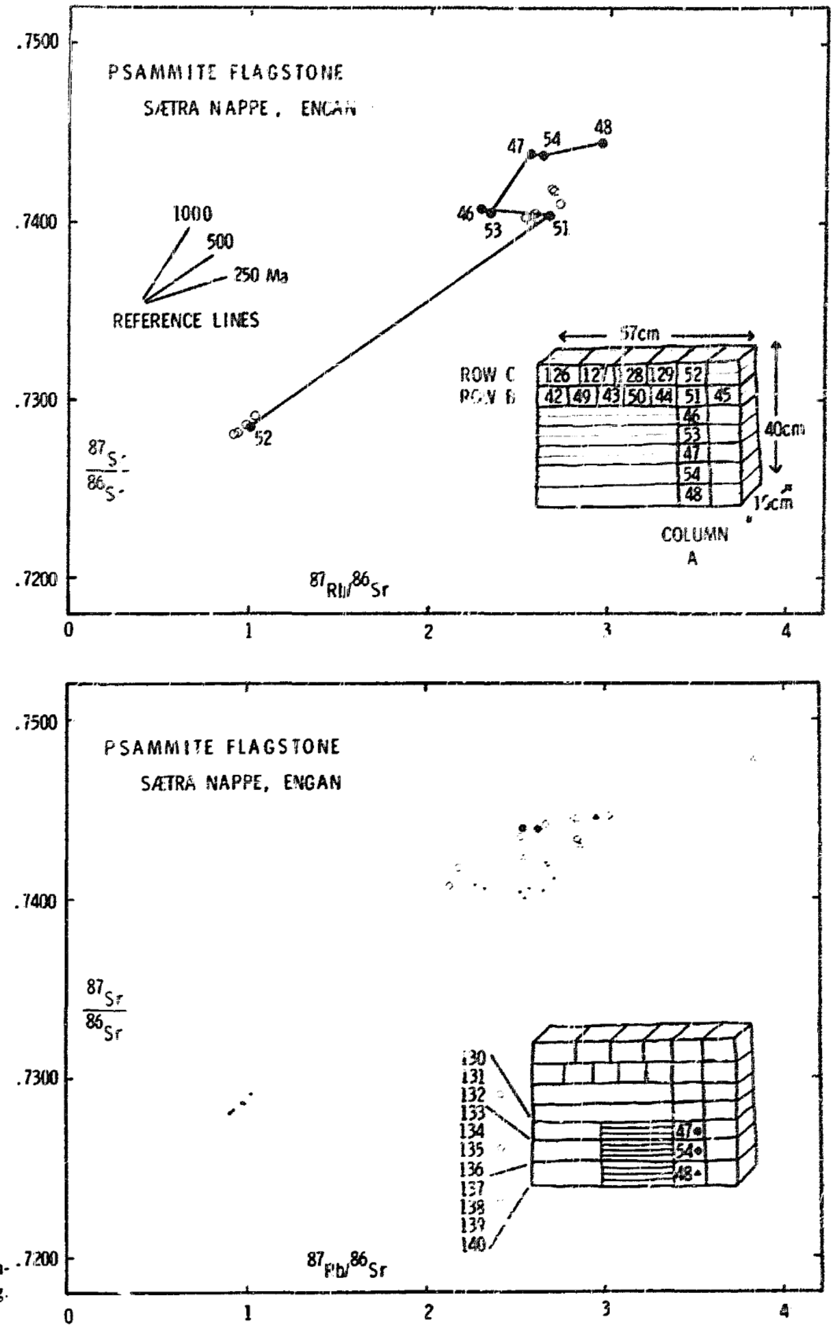

Fig. 9. Sketch of psammite sample block and Rb-Sr plots. Fig. 9a above. 9b below.

^{86}Sr values were never equilibrated to a single value on this whole-rock scale.

At some very small scale, isotopic equilibration must have occurred during the Caledonian orogeny, because whole-rock/mineral systems in this part of the Western Gneiss Region have given Caledonian isochrons (Solheim 1980; Krill unpubl. data). To test a smaller whole-rock scale, eleven more samples were analysed from the bottom three rows of the block (Fig. 9b). As in the larger system, the isotopic values are closely related within the newly defined rows; samples 130, 131, and 132 together make the same row and have about the same average isotopic value as specimen 47 (Fig. 9b). Isotopic similarity holds also within the rows defined by samples 54 and 48.

Since the $^{87}Sr/^{86}Sr$ values were not equilibrated, various positive slopes obtained from the sets of samples are not accurate metamorphic or secondary ages; they reflect the mineralogical composition, and thus the provenance, of the psammite. However, the various slopes do not accurately indicate the ages of the provenance rocks. The isotopic values were probably modified during weathering, transportation, and deposition of the sediments, before they were modified by any partial equilibration during metamorphism of the psammite. The various slopes defined by points from within single rows may be meaningful, but further study would be necessary before they could be interpreted.

The earlier isochron date of 1035 Ma (Solheim 1980) might be a meaningful pre-metamorphic provenance age, but it is not the date of metamorphism or secondary disturbance of the psammite. Indeed, it could be a 'false date' – a mixing line between distinct end-member compositions that were not equilibrated during the deformation. Such a mixing line could easily be obtained by completely routine sampling of the layered but unequilibrated flagstone. For example, samples representing a mixture of rows 51 and 52 (Fig. 9a) would define a false date of about 500 Ma, and samples from rows 47 and 53 would suggest a date of 1000 Ma.

Conclusions

The geologic and geochronologic data lead to the conclusion that the dolerite dikes intruded unmetamorphosed psammites about 745 ± 37 Ma ago. The Sætra Nappe was then thrust emplaced and metamorphosed together with other rocks of this part of the Western Gneiss Region during the Caledonian orogeny. The metamorphism was completed at least by 365 Ma, as indicated by the youngest Rb-Sr mineral dates of the area (Krill unpubl. data).

Neither the psammite nor the metadolerite show resetting of the whole-rock dates, despite the generally strong Caledonian orogenesis of the region. These conclusions are consistent with other geochronologic results from the eastern margin of the Western Gneiss Region; Caledonian schists were not fully equilibrated by the orogenesis, and Precambrian gneisses were generally not re-equilibrated. A comparison with results from gneiss regions in other orogens (Krill & Griffin 1981) shows that whole-rock Rb-Sr dates are commonly preserved, rather than reset. However, some cases of resetting have been well documented (Field & Råheim 1979, with references), and no general statements can be made as to what degree of metamorphism and deformation *may* reset or *must* reset whole-rock systems. Isochrons and errorchrons must be interpreted, and sometimes re-interpreted, either as primary, secondary, or even meaningless dates, on the basis of all available isotopic and geologic evidence.

Appendix

Analytical techniques

The samples were crushed in a steel-jaw crusher and finely ground in a steel-ring mill. Rb/Sr ratios of the psammite samples and dike sample 204 were determined directly by X-ray fluorescence (Pankhurst & O'Nions 1973). Rb and Sr contents of the dolerite samples were determined by isotope dilution using a mixed $^{87}Rb/^{84}Sr$ spike. Variable mass discrimination in $^{87}Sr/^{86}Sr$ was corrected by normalizing $^{88}Sr/^{86}Sr$ to 8.3752. Mass spectrometry was performed on a Micromass MS30. The ^{87}Rb decay constant used was 1.42×10^{-11} yr^{-1}, and the data were regressed by the method of York (1969). In assigning errors, the coefficient of variation was taken as 1 % for $^{87}Rb/^{86}Sr$. The errors for the $^{87}Sr/^{86}Sr$ measurements are listed in Table 3. Age and intercept errors are quoted at the 2-sigma confidence level.

Dike locations and petrographic descriptions

Dolerite dike 'M' was freshly exposed by new road blasting between two flagstone quarries east of highway E6 (Universal Transverse Mercator Grid Zone Location 32VNQ29892637). The dike is a very irregularly shaped stepped intrusion. It is strongly foliated within a few centimeters of the margin, but is generally weakly foliated. The samples were collected from a small unfoliated part in the center of the dike where it is about 3 m wide. The metadolerite samples display relict fine-grained subophitic texture. Plagioclase is albite twinned and contains some needles of metamorphic zoisite. Cores of clinopyroxene grains are largely uralitized to diffuse intergrowths of hornblende and epidote, whereas clinopyroxene rims are replaced by well crystallized blue-green hornblende. Opaques show skeletal textures. No chlorite or biotite are observed.

Dike 'D' is located east of Oppdal Skiferindustri flagstone-storage yard, UTM location 32VNQ29622595. The dike is strongly foliated at the margin, but all samples are from the massive central part, at least 1 m from the psammite. The dolerite displays relict subophitic texture. Plagioclase shows albite twins and contains abundant zoisite needles. Relict pyroxene is generally replaced by fine-grained epidote and hornblende. Well crystallized blue-green hornblende is common. Opaques show skeletal textures. No chlorite or biotite are observed.

Dike 'A' is between two quarries south of Oppdal Skiferindustri. UTM location 32VNQ29692553. The dike is foliated at the margin, with the psammite strongly folded against it. Both samples are from the massive central part, about 1 m from the nearest psammite. Abundant rusty-weathering joint surfaces were unavoidable in sampling. Plagioclase displays some faint albite twins and contains abundant zoisite. Clinopyroxene is generally completely replaced by well crystallized blue-green hornblende. Opaques show skeletal textures. Traces of randomly oriented, poorly crystallized biotite and chlorite are observed.

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