Rb–Sr whole rock ages from Magerøy, North Norwegian Caledonides

TORGEIR B. ANDERSEN, HÅKON AUSTRHEIM, BRIAN A. STURT, SVEND PEDERSEN, & KENNETH KJÆRSRUD

Andersen, T. B., Austrheim, H., Sturt, B. A., Pedersen, S. & Kjærsrud, K. Rb–Sr whole rock ages from Magerøy, North Norwegian Caledonides. *Norsk Geologisk Tidsskrift,* Vol. 62, pp. 79–85. Oslo 1982. ISSN 0029-196X.

Two Rb-Sr whole rock isochrons from the Gjesvær Migmatite Complex (410 ± 28 m.y., IR:0,75472 ± 0,0015) and the Finnvik Granite (411 ±7 m.y., IR:0,7116 ±0,0010) within the orthotectonic Caledonides of northernmost Norway are presented. The syn-orogenic Finnvik Granite cuts folded Llandoverian strata of the Magerøy Nappe and was intruded coevally with the peak of the Scandinavian Phase regional metamorphism. This granite thus occupies a critical position for the dating of the Scandinavian Phase of the Caledonian Orogeny in the region. The regional metamorphism during this phase resulted in Rb–Sr isotope homogenization in the older Gjersvær Migmatite Complex which underlies the basal thrust of the Magerøy Nappe. The re-set age of this complex gives the same age as the syn-metamorphic Finnvik granite. A model age calculation for the migmatites gives 1335 m.y., indicating that the provenance rocks of the sedimentary protolith to the Gjesvær Migmatite Complex were probably an old Precambrian terrain. The age of the Scandinavian Phase in the Scandinavian Caledonides is discussed in relation to the chrono- and biostratigraphic evidence presently available.

Torgeir B. Andersen and Brian A. Sturt, Geologisk institutt avd. A, 5014 Universitetet i Bergen, Norway
Håkon Austrheim, Geologisk Museum, Sarsgt. 1, Oslo 5, Norway.
Svend Pedersen, Institut for Almen Geologi, Øster Voldgade 10, 1350 København, Denmark.
Kenneth Kjærsrud, A/S Sulfidmalm, Falconbridge, 4600 Kristiansand (S), Norway.

Introduction

It is now clear that the evolution of the Scandinavian Caledonides involved two major stages of tectono-metamorphic development. The two phases have been termed the Finnmarkian and the Scandinavian Phase (Ramsay & Sturt 1976, Sturt et al. 1978, Roberts & Gale 1978). The Finnmarkian Phase is broadly coeval with the Grampian Phase in the British Isles (Ryan & Sturt 1981), and also with the obduction of ophiolitic assemblages onto the Baltic Shield (Furnes et al. 1980). Evidence of Finnmarkian orogenesis is also available from the Trondheim region where trondhjemitic rocks dated at around 450–480 m.y. intrude already deformed Cambrian rocks (Klingspor & Gee 1981).

The Scandinavian Phase was responsible for the transport of great thrust nappes which presently dominate the pattern of tectono-stratigraphic units in the Scandinavian Caledonides. In this paper two Rb–Sr whole rock isochrons from the island of Magerøy positioned within the orthotectonic Caledonides of northernmost Norway are presented, and they are considered to date the age of the Scandinavian Phase metamorphic maximum in this region.

Geological setting

The rocks on Magerøy comprise three tectonic units (Fig. 1). In ascending tectono-stratigraphic order these are the Gjesvær Migmatite Complex, the Magerøy Nappe and the Skarsvåg Nappe (Curry 1975, Ramsay & Sturt 1976, Andersen 1979, 1981). Geochronological data from the two lower units are presented. The highest unit, the Skarsvåg Nappe, is a small erosional klippe of migmatitic mica schists and quartzites of unknown age. The emplacement of the nappe shown by its superimposition on the Magerøy Nappe, however, is of Scandinavian Phase age (Andersen 1981).

The Magerøy Nappe constitutes the major part of the island, and is underlain to the west by the Gjesvær Migmatite Complex. The two complexes are separated by a major thrust (Ramsay & Sturt 1976). The lithologies of the nappe are composed chiefly of a polyphasally deformed and metamorphosed upper Ordovician to lower Silurian sedimentary sequence with a minimum stratigraphic thickness of 5.5 km. In addition, syntectonic igneous rocks of two main types occur. In the Honningsvåg area a major layered mafic-ultramafic complex (Curry 1975) occurs, and in

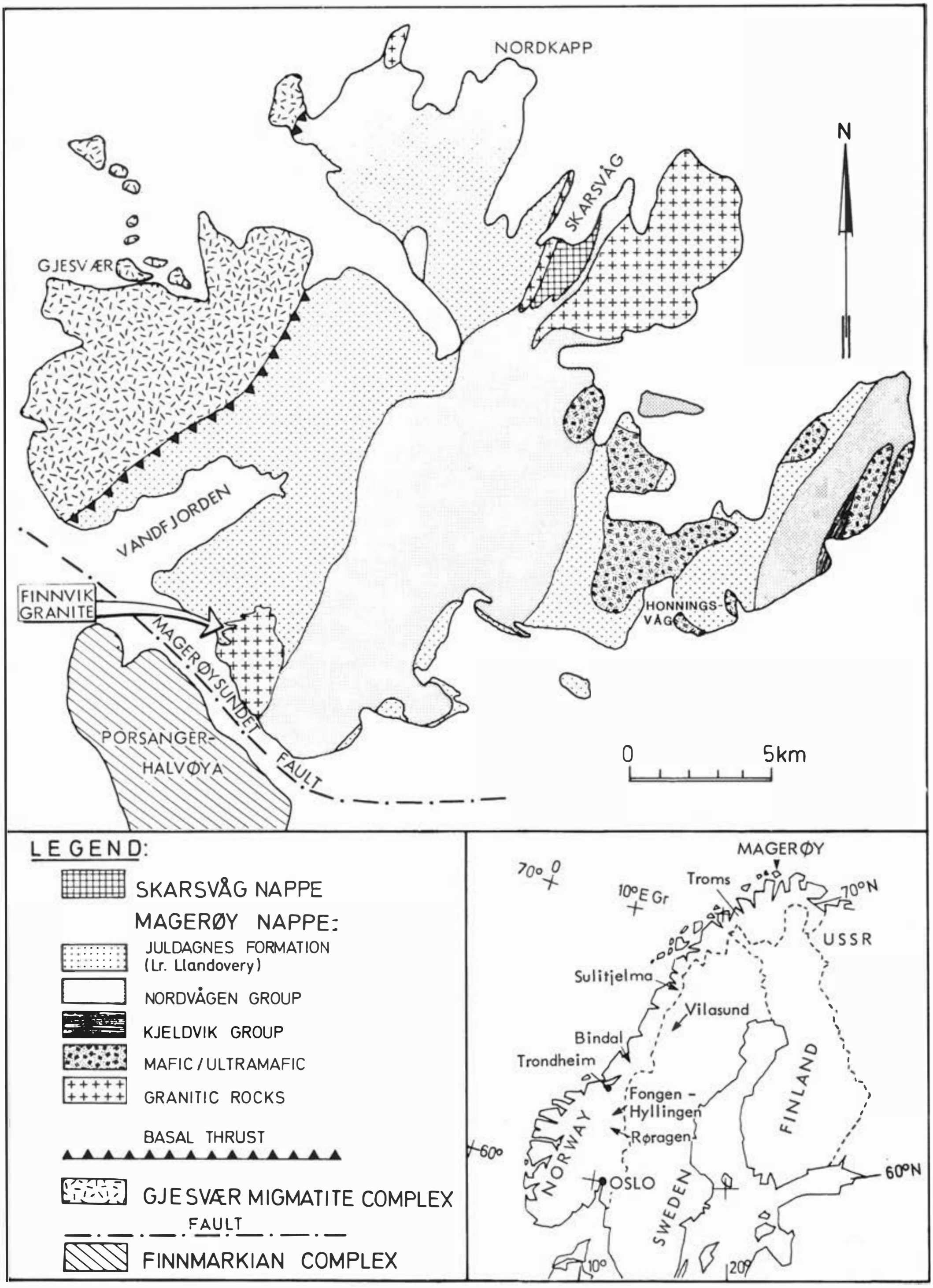

Fig. 1. Simplified geological map of Magerøy.

the central and eastern parts of the nappe a series of granites and granitoids have been intruded (Andersen 1979).

The dated lithology from the Magerøy Nappe is the *Finnvik Granite*, which is located in the southern part of Magerøy, where it occupies an area of 7.75 km^2.

The intrusion has the composition of a true granite, and is chiefly composed of quartz, microcline, albite and biotite. Rutile, tourmaline, zircon and amphibole occur as accessory minerals. Chlorite, muscovite and epidote are found as secondary minerals. The granite is commonly medium grained, but in some areas it is porphyritic with microcline phenocrysts up to 4 cm in length. The Finnvik Granite intrudes the youngest formation of the Magerøy Supergroup (Andersen 1979). In the Honningsvåg area, this formation contains *Monograptus sandersoni*, which indicates that the sequence ranges in age at least up into the lower Llandovery (Sturt et al. 1975). The country rocks to the granite were already in amphibolite facies by the time of granite intrusion (Andersen 1979). The granite has a cross-cutting relationship to the D 1 structures, and apophyses of the granite intrude both along and transgress the penetrative S 1 foliation. The apophyses were folded and boudinaged during the Scandinavian Phase D 2. This deformation has resulted, for the D 2 strained parts, in a strong undulose extinction in both quartz and feldspar, and recrystallization to polygonal grain mosaics may observed. The granite has undergone intense brittle deformation along its southern margin, and this is apparently related to cataclasis along the Magerøysundet Fault.

The other dated lithology is the migmatitic paragneisses of the Gjesvær Migmatite Complex underlying the Magerøy Nappe (Ramsay & Sturt 1976). The samples analyzed were collected from the area around the village of Gjesvær, which is structurally positioned 2–3 km beneath the Magerøy Nappe thrust plane. This complex is chiefly formed by migmatized psammites. In addition, zones of calc-silicate lithologies and quartzites which are virtually unaffected by anatexis occur, and the quartzites locally preserve primary sedimentary structures. Gradual transitions from migmatite to quartzite occur, both on the scale of bedding and between larger rock bodies, and this shows that the development of partial melts was strongly controlled by the bulk composition where arkosic members have been migmatized. Basic sheets, now garnet amphibolites, are common in zones.

The Gjesvær Migmatite Complex has evidence of a protracted tectono-metamorphic history (Ramsay & Sturt 1976). Two early penetrative deformational events associated with elevated temperatures which produced anatectic melts have been discerned. The basic sheets were emplaced essentially during the first of these deformational events, and they are extensively net-veined by leucocratic neosome. There is evidence to show that this protracted tectono-metamorphic and intrusive history occurred prior to the emplacement of the Magerøy Nappe. This is demonstrated by the relationship of the early structures and fabrics to the thick development of blastomylonites which were established during the emplacement of the Magerøy Nappe (Ramsay & Sturt 1976). The early deformation and anatexis are assigned to the Finnmarkian Phase as they show striking similarity to the deformation and metamorphism characterizing the Finnmarkian terrain in the Porsanger – halvøya and the Hjelmsøy area immediately south-west of Magerøy (Ramsay et al. 1979, Ramsay et al. 1981).

The emplacement of the Magerøy Nappe occurred during the Scandinavian Phase D 1 (Andersen 1981). A thick zone of blastomylonites was developed from the already migmatized rocks of the Gjesvær Migmatite Complex. The thrusting took place at amphibolite facies metamorphism, but at temperatures, in the thrust zone, below those required for partial melts to develop. At deeper structural levels in the migmatite complex, where the thrust-related strains were lower, only a gentle folding and an associated planar structure developed (Andersen 1979). Neosomal material was produced, and in several localities it intrudes along the planar structure. In most areas the fabric correlated to the Scandinavian Phase D 1 is absent, and in such areas it is not possible to relate leucocratic veins and nebulitic segregations directly to the Scandinavian Phase.

The migmatites collected for this study are the typical relatively homogenous background migmatites, and not the obvious late neosomal segregations described above. The mineralogy of these migmatites is quartz, plagioclase (An 26–32), microcline, biotite, muscovite, garnet and accessory zircon, tourmaline, apatite and ilmeno-magnetite (Ramsay & Sturt 1976). The sampling

Table 1. Whole rock analytical data from the Finnvik Granite.

Sample	Rb/Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
PL 837	3,41	9,96 ± 7	0,7698 ± 2
PL 847	3,48	10,11 ± 7	0,7712 ± 2
PL 1137*	6,18	18,25 ± 13	0,8216 ± 2
PL 1147	9,02	26,72 ± 19	0,8669 ± 5
PL 1157*	3,43	10,04 ± 7	0,7720 ± 2
PL 1167	2,83	8,24 ± 7	0,7593 ± 2
PL 1177	3,29	9,63 ± 7	0,7686 ± 2
PL 1187	2,77	8,13 ± 6	0,7590 ± 2
PL 1197	8,60	25,52 ± 18	0,8615 ± 5

* omitted from isochron calculation

was carried out away from the contact with the overlying Magerøy Nappe to test if the pronounced recrystallization of the blastomylonites in the thrust zone was an effect of a hot overriding nappe, or whether it was a result of a regional geothermal gradient also affecting the basement at deeper levels below the thrust zone. The samples were collected along a profile approximately 350 m long on an island immediately north of the village of Gjesvær (Fig. 1).

Analytical techniques

A) Finnvik Granite (Table 1)

The Rb/Sr ratios were measured directly on two pellets of each sample on the Phillips pw 1410 XRF spectrometer of the Institute of Petrology, University of Copenhagen. Errors (1σ) were calculated from the counting statistics and from the differences between the standards used. GSP-1 and G-2 were used as standards, and Rb/Sr ratios of 1.093 and 0.355 respectively were assigned to these standards. While measuring the Finnvik granite samples, the NBS-70A and NBS-607 k-feldspar standards were also analysed. Values of 8.07 ± 6 and 8.02 ± 6 respectively were obtained. Unspiked measurements of the $^{87}Sr/^{86}Sr$ ratios were made using the Varian MAT TH-5 mass spectrometer of the Institute of Petrology, University of Copenhagen. The $^{87}Sr/^{86}Sr$ ratios measured are corrected to a $^{87}Sr/^{86}Sr$ value for the Eimer and Amend $SrCO_3$ of 0.7080 normalized to a $^{88}Sr/^{86}Sr$ value of 8.3752. The errors quoted (1σ) were calculated from a suite of 20 double determinations (including the chemistry) carried out at the laboratory some time before the investigation. Ages were calculated using a decay constant of 1.42×10^{-11}/year. All Rb/Sr

Table 2. Whole rock analytical data from the Gjesvær migmatites.

Sample	Rb	Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	SE
GJ 26	195.4	140.1	4.062	0.77850 ± 0.00006	
GJ 27	197.9	137.8	4.183	0.77915 ± 0.00005	
GJ 28	191.4	134.3	4.154	0.77886 ± 0.00006	
GJ 29	163.6	125.5	3.827	0.77704 ± 0.00005	
GJ 30	192.2	135.2	4.144	0.77911 ± 0.00018	
GJ 32	159.3	145.8	3.180	0.77310 ± 0.00016	
GJ 33	166.7	140.0	3.449	0.77486 ± 0.00009	
GJ 34	172.5	143.8	3.495	0.77507 ± 0.00009	
GJ 35	191.2	140.3	3.971	0.77798 ± 0.00007	
GJ 36	183.3	139.0	3.947	0.77775 ± 0.00008	
GJ 37	169.8	133.9	3.694	0.77618 ± 0.00009	
GJ 38	201.5	136.4	4.306	0.77946 ± 0.00011	
GJ 39	162.5	138.6	3.415	0.77478 ± 0.00009	
GJ 40	179.5	146.5	3.722	0.77656 ± 0.00009	
	Rb	Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$*	
	180.5	137.9	3.813	0.77696	

* obtained by substituting $^{87}Rb/^{86}Sr$ value into the equation that defines the isochron.

ages quoted in this paper have been recalculated to this decay constant. Errors in age and initial ratio (I.R.) are given at the 2σ level.

B) The Gjesvær Migmatite Complex (Table 2)

Rb/Sr ratios were determined directly (Geological Museum, Oslo) by an XRF method using Compton top matrix correction. Unspiked measurements of the $^{87}Sr/^{86}Sr$ ratios were made. Variable mass discrimination was corrected by normalizing the $^{88}Sr/^{86}Sr$ to 8.3752. Mass spectometry was performed on a VG Micromass MS 30 (Geological Museum, Oslo) using procedures similar to those described by Pankhurst & O'Nions (1973). The data have been regressed by the technique of York (1969). In assigning errors to the data points, the coefficient of variation is taken as 1% for the $^{87}Rb/Sr$ ratios; the within-run errors for the $^{87}Sr/^{86}Sr$ measurements are given in Table 2 (1σ standard error of mean).

Results

A) The Finnvik Granite (Fig. 2)

The regression of all 9 samples from the Finnvik Granite gives a line which corresponds to the age 417 ± 6 m.y. with an initial $^{87}Sr^{86}Sr$ ratio of 0.7110 ± 0.0010. The high MSWD value of 3.9

shows that the scatter around this line is higher than that which can be assigned to analytical errors alone.

The exact significance of the deduced age cannot therefore be ascertained unless we know the geological reason for this scatter. In the present case we propose that the scatter is due to a part opening of the total rock system during the Scandinavian phase D-2, or possibly during the movements along the Magerøysundet Fault (Andersen & White, in press), and that this (these) later event(s) caused some of the samples to fall off the original isochron. If the samples PL 1137 and PL 1157 which caused the high MSWD value are excluded from the regression analysis, the remaining 7 samples define an isochron (MSWD 1.2) that corresponds to an age of 411 ± 7 m.y. with an I.R. of 0.7116 ± 0.0010. We regard this as the best age estimate for the Finnvik Granite. An alternative interpretation could be that the two samples had a different I.R., in which case the age 417 ± 6 m.y. would be the best estimate.

B) The Gjesvær Migmatite Complex (Fig. 3)

A regression analysis of the 14 samples from this complex gives an isochron which corresponds to an age of 410 ± 28 m.y. with a high I.R. of 0.75472 ± 0.0015. This age is regarded as the final event of migmatization. However, from the geological evidence as argued above, it is clear that the complex has experienced a protracted tectono-metamorphic history, including anatexis, prior to the final event of Scandinavian phase age. The MSWD value of 0.35 shows that the scatter can be assigned to analytical errors, which means that the Scandinavian phase regional metamorphism caused complete homogenization of Rb–Sb isotopes. The samples from localities several hundred metres apart indicate that the re-setting in the Gjesvær Migmatite Complex occurred on a regional scale.

The high I.R. shows that the protolith to the Gjesvær Migmatite Complex has a protracted crustal history prior to the final isotope homogenization. A sedimentary origin of the migmatites has been argued above, and the paragneisses of the complex have been lithostratigraphically correlated with the Klubben Psammite Group (see page 81). The Rb/Sr data do not allow us to comment on the time of sedimentation. However, by assuming an I.R. of 0.704 – a realistic mantle value in the actual case – the $^{87}Sr/^{86}Sr$ value of the Gjesvær Migmatite

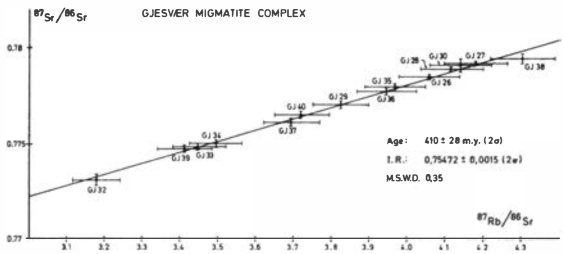

Fig. 2. Rb–Sr isochron plot for the Finnvik Granite. Samples 1137 and 1157 not included in the isochron calculation. Errorbars indicate 2σ errors.

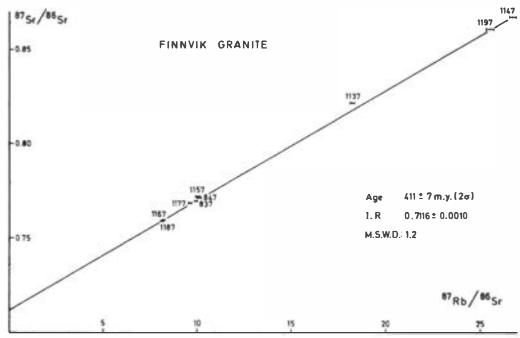

Fig. 3. Rb–Sr isochron plot for the Gjesvær Migmatite Complex Errorbars indicate 2σ errors.

Complex gives a model age of 1335 m.y. This indicates that at least some of the provenance rocks for the sedimentary protolith to the Gjesvær Migmatite Complex could have been of old Precambrian age.

Discussion

It has been argued that the intrusion of the Finnvik Granite coincides with the peak of the Scandinavian Phase metamorphism in the northernmost segment of the Scandinavian Caledonides. The granite cuts folded lower Llandoverian strata and this brackets the age for the onset of the Scandinavian Phase orogenic deformation in Magerøy. In the Sagelvvatn area of north Troms a shelly fauna of upper Llandovery age has been recognized within the metamorphic allochthon (Bjørlykke & Olaussen 1981) and gives the minimum stratigraphic constraint of the Scandinavian Phase deformation recognized until now in the Scandinavian Caledonides. In the Seve-Køli complex of Sweden, the Trondheim region and in the West-Norwegian Caledonides, lower Llandoverian faunas give maximum ages for the Scandinavian Phase (Gee & Wilson 1974, Gee 1978, Roberts 1978 , Ryan & Skevington 1976, Thon 1981). In many of these areas the fossiliferous strata are overlain by considerable sedimentary sequences, so it seems plausible that an upper Llandovery age as indicated in the Sagelvvatn area marks the minimum stratigraphic constraint to the Scandinavian Phase of the Caledonian Orogeny. An upper constraint to this phase is given by the Old Red Sandstone sediments of Trøndelag which possibly extend down into the Ludlovian (Siedlecka 1975).

The Rb-Sr whole rock isochron from late differentiates in the Fongen-Hyllingen intrusion in the Trondheim region (405 ± 9) provide an important time marker for the Scandinavian Phase as both the intrusion and its envelope suffered deformation prior to the deposition of the lower Devonian sediments of Røragen (Wilson 1981). The Vilasund Granite (435 ± 6) was previously regarded as representing an important marker for the age of the Scandinavian Phase, as it was thought to cut lower Llandoverian rocks (Gee & Wilson 1974). The same authors (pers. comm. in Gale et al. 1979), however, now state that a tectonic discontinuity separates the granite and its envelope from the fossiliferous sequence. It is thus possible that it represents a post-Finnmarkian Phase – pre-Scandinavian Phase pluton, and consequently has been intruded in this period (Ordovician) which one now realizes to be important for widespread acidic igneous activity (Ryan & Sturt 1981). Rb–Sr whole rock dating of syntectonic Scandinavian Phase granites is relatively sparse but the granites from which geochronological data exist fall within the same age patterns as the date presently presented from Magerøy.

From the Sulitjelma area of central North Norway, Wilson (1981) reports three Rb–Sr whole rock isochrons of 424 ± 11, 418 ± 14 and 422 ± 8 m.y. These are from post-D 1 pre-D 2 granites, and they have been intruded after thrusting which affects fossiliferous rocks of probable upper Ordovician age. A comparison between ages from Magerøy and Sulitjelma indicates a diachronism of the Scandinavian Phase, with slightly higher ages of the syn-tectonic plutons and dykes from the Sulitjelma area. Some overlap exists, however, and further carefully designed studies would be required in order to substantiate this suggestion. The Bindal Granite with an age of 413 ± 26 m.y. (Priem et al. 1975) falls within the same age group, but with such an error that it is not possible to point to any diachronism with respect to the belt length development of the Scandinavian Phase.

On the basis of the stratigraphical arguments from within the metamorphic allochthon, the age of the tectono-metamorphic cycle of the Scandinavian Phase can be bracketed to a Wenlockian – Ludlovian age, in general agreement with the conclusions of Gee & Wilson (1974). Independent support for this is that in the Caledonian foreland sequence of the Oslo region, the widespread sedimentation of continental sandstones starts in the upper Wenlock (graptolite zone M. ludensis), and has traditionally been regarded to be a sedimentary response to a rising mountain belt to the west.

Conclusions

The Finnvik Granite of northernmost Norway was emplaced at 411 ± 7 m.y., and cuts folded rocks of lower Llandovery age. The granite is syn-orogenic, intruded between D 1 and D 2, and at the maximum of the Scandinavian Phase regional metamorphism. The metamorphism affects the pre-Scandinavian Phase basement (Finnmarkian ?) onto which the Magerøy Nappe was emplaced. This resulted, in Magerøy, in isotope homogenization and the re-setting of the Rb–Sr radiometric clock at 410 ± 28 m.y. The Finnvik Granite occupies a critical position for the dating of the Scandinavian Phase regional metamorphism.

The biostratigraphy from within the metamorphic allochthon indicates a Wenlockian to Ludlovian age for the Scandinavian Phase of the Caledonian Orogeny. The new radiometric dates presented are in relatively good accordance with the numerical calibration of the lower Palaeozoic timescale by Ross et al. (1978), and also with the compromise timescale suggested by Gale et al. (1980).

Received March 1982

References

Andersen, T. B. 1979: *The geology of south-west Magerøy; with special reference to the tectono-metamorphic development.* Unpublished Cand. real. thesis, Univ. of Bergen. 338 pp.

Andersen, T. B. 1981: The structure of the Magerøy Nappe, Finnmark, North Norway. *Nor. geol. unders. 363,* 1–23.

Bjørlykke, A. & Olaussen, S. 1981: Silurian sediments, volcanics and mineral deposits in the Sagelvvatn area, Troms, North Norway. *Nor. geol. unders. 365,* 1–38.

Curry, C. J. 1975: *A regional study of the Magerøy basic igneous complex and its envelope.* Unpublished Ph. D. thesis, Univ. of Dundee 244 pp.

Furnes, H., Roberts, D., Sturt, B. A., Thon, A. and Gale, G. H. 1980: *Ophiolite fragments in the Scandinavian Caledonides. In: Ophiolites,* Proc. Intern. Ophiolite symp. Cyprus 1979. 582–600.

Gale, N. H., Beckinsale, R. D. & Wadge, A. J. 1980: Discussion of a paper by McKerrow, Lambert and Chamberlain on the Ordovician, Silurian and Devonian time scales. *Earth Planet. Sci. Lett. 51,* 9–17.

Gee, D. G. 1978: The Swedish Caledonides – A short synthesis. In: Caledonian-Appalachian Orogen of the North Atlantic Region. *Geol. Surv. of Canada. Paper 78–13,* 63–72.

Gee, D. G. & Wilson, M. R. 1974: The age of orogenic deformation in the Swedish Caledonides. *Am. J. Sci. 274,* 1–9.

Klingspor, I. & Gee, D. G. 1981: Isotopic age – determination studies of the Trøndelag trondhjemites. Abstract. Uppsala Caledonide Symposium, *Terra cognita, 1,* 1–55.

Priem, H. N. A., Bodrijk, N. A. I. M, Hebeda, E. H., Verdurmen, E. A. T. & Verschure, R. H., 1975: Isotopic Dating of the Caledonian Bindal and Svenningdal granitic massifs, Central Norway. *Nor. geol. unders. 319,* 29–36.

Ramsay, D. M. & Sturt, B. A. 1976: The syn-metamorphic emplacement of the Magerøy Nappe. *Nor. Geol. Tidsskr. 56,* 291–307.

Ramsay, D. M., Sturt, B. A. & Andersen, T. B. 1979: The sub-Caledonian uncomformity on Hjemsøy – New evidence of primary basement/cover relations in the Finnmarkian Nappe sequence. *Nor. geol. unders. 351,* 1–12.

Ramsay, D. M., Sturt, B. A., Jansen, Ø., Andersen, T. B. & Roy, S. S. 1981: The tectono-stratigraphy of western Porsangerhalvøya and Kvaløy, Finnmark, Nort Norway. Abstract, Uppsala Caledonide Symposium, *Terra cognita 1,* 1–68.

Roberts, D. 1978: Caledonides of south central Norway. In: Caledonian-Appalachian Orogen of the North Atlantic Region. *Geol. surv. of Canada. Paper 78–13,* 31–37.

Roberts, D. & Gale, G. H. 1978. The Caledonian-Appalachian Iapetus ocean. *In* Tarling, D. H. (ed.) "Evolution of the Earth's crust", Academic Press, London, New York, 255–312.

Ross, R. J., Naeser, C. W., Izett, G. A., Whittington, H. B., Hughes, C. P., Richards, R. B., Zalasiewicz, J., Sheldon, P. R., & Jenkins, C. J. 1978: Fission-track dating of lower Palaeozoic volcanic ashes in British stratotypes. Short paper of the Fourth International Conference on Geochronolog-Cosmochronology, Isotope Geology. *U.S. Geological Survey Open-File Report 78–701.*

Ryan, P. A. & Skevington, D. 1976: A reintrepretation of the late Ordovician – early Silurian stratigraphy of the Dyvikvågen and Ulven-Vaktdal areas, Hordaland, W. Norway. *Norges geol. unders. 324,* 1–20.

Ryan, P. A. and Sturt, B. A. 1981: Early Caledonian orogenesis in North-western Europe. Abstract, Uppsala Caledonide Symposium, *Terra cognita 1, 1,* 71.

Siedlecka, A. 1975: Old Red Sandstone lithostratigraphy and sedimentation of the outer Fosen area, Trondheim region. *Nor. geol. unders. 321,* 1–35.

Sturt, B. A., Pringle, I. R. and Roberts, D. 1975: Caledonian nappe sequence of Finnmark, northern Norway and the timing of orogenic deformation and metamorphism. *Geol. Soc. Am. Bull. 86,* 710–718.

Sturt, B. A., Pringle, I. R. & Ramsay, D. M., 1978: The Finnmarkian Phase of the Caledonian Orogeny. *J. Geol. Soc. London 135,* 597–610.

Thon, A. 1981: Middle/upper Ordovician cover sequences to the west Norwegian ophiolite fragments: Stratigraphy and structural evolution. Abstract. Uppsala Caledonide Symposium, *Terra cognita 1, 1,* 78.

Wilson, J. R. 1981: The synorogenic Fongen-Hyllingen layered basic intrusions, Trondheim region, Norway – A review. Abstract. Uppsala Caledonide Symposium, *Terra cognita 1,* 1, 82.

Wilson, M. R. 1981: Geochronological results from Sulitjelma, Norway. Abstract. Uppsala Caledonide Symposium, *Terra cognita 1, 1,* 82.

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