U-Pb zircon age of the Møklevatnet granodiorite, Gjersvik Nappe, Central Norwegian Caledonides

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The Møklevatnet granodiorite in the Gjersvik Nappe has yielded a U-Pb zircon age of 456 ± 2 Ma from three, concordant, multigrain fractions. This can also be regarded as a maximum age, Early Middle Caradoc, for the oldest sediments in the unconformably overlying Limingen Group. Taken in conjunction with isotopic data reported earlier, the zircon age for the Møklevatnet pluton indicates that the magmatic activity represented in the Gjersvik Nappe extended over a period of 25 to 30 million years.

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Introduction

Of the several Köli Nappes in the Upper Allochthon of the Caledonides in Nord-Trøndelag, Central Norway, the Gjersvik Nappe has the most voluminous igneous component, comprising a thick bimodal volcanic assemblage and coeval to younger plutonic bodies (Halls et al.1977, Lutro 1979, Reinsbakken 1980). Lying unconformably upon the eroded magmatic complex is a sequence of low-grade polymict conglomerates, calcareous sandstones, phyllites and thin volcanites, the Limingen Group, of unknown but hitherto assumed Late Ordovician/Early Silurian age.

While the age of the sub-Limingen magmatic complex has generally been assumed to be Early to Middle Ordovician (Gale & Roberts 1974, Halls et al.1977), no isotopic dating had been available until Kullerud et al. (1988) produced a U-Pb zircon age of 483 ± 4 Ma for a foliated concordant trondhjemite body. In this contribution we report a U-Pb zircon age from one of the youngest but most extensive plutons in this magmatic complex — the Møklevatnet granodiorite.

Geological setting

The Møklevatnet granodiorite is a dominating element in the geology of the Grong region (Roberts 1989) and conspicuous even at 1:1 million scale (Sigmond et al.1984). Covering an area of close to 400 km^2 it is situated in the southernmost part of the Gjersvik Nappe where it has been variously described as trondhjemite, quartz diorite or granodiorite (Gale 1975, Halls et al. 1977, Kollung 1979) (Fig.1). Gale (1975) referred to the body informally as the Sanddøla trondhjemite. However, since the valley Sanddøla is located south of the exposed southern limit of the pluton, we prefer a more appropriate and acceptable geographic designation; and suggest the name Møklevatnet. Also, it can be demonstrated that, in the Møklevatnet area, the rock is a granodiorite rather than a trondhjemite (see below).

Field relationships of the plutonic members of the igneous complex in this southern part of the Gjersvik Nappe have been described and discussed mainly by Gale (1975) and Halls et al. (1977). Gabbros intrude the volcanites but these are in turn cut by, and enclosed as xenoliths within the granodiorite, which thus appears to be the youngest plutonic body in this area. The gabbro and granodiorite are, however, considered to be broadly cogenetic. The ratio of rafts of gabbro, volcanites and some schists to the enclosing granodiorite in some areas is quite high, so much so that Gale (1975) considered these localities to be situated within the roof zone of the pluton. The granodiorite displays a variable but locally pervasive foliation which parallels the schistosity in both the older volcanites and the younger sediments. This is regarded as a metamorphic fabric dating to the Late Silurian, Scandian orogenesis. No older, pre-granodiorite, foliate structure has been recorded from the rocks of the Gjersvik Nappe. The south-

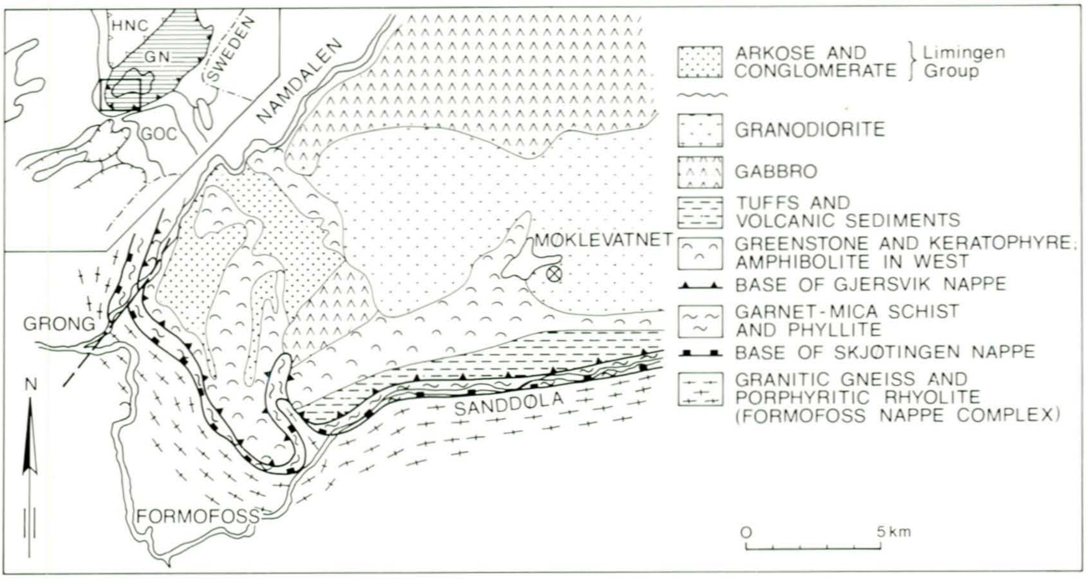

Fig.1. Simplified geological map of the southwestern part of the Gjersvik Nappe, showing the location (circled cross) of the dated granodiorite sample near Møklevatnet. The granodiorite extends over a larger area further east where it is direct contact with the overlying basal sediments of the Limingen Group (Gale 1975, Kollung 1979). In the inset map, GN = Gjersvik Nappe, HNC = Helgeland Nappe Complex and GOC = Grong-Olden Culmination.

ern boundary of the granodiorite north of Sanddøla (Fig.1), in contact with volcanic and sedimentary rocks, is locally tectonised, in places quite strongly, a feature arising from competency contrasts between lithologies rather than major thrust-faulting.

A previous attempt at dating the body, by the Rb-Sr method, using 3 granodiorite samples together with one sample of assumed cogenetic gabbro, produced an isochron age of 433 ± 10 Ma with an initial Sr ratio of 0.70427 (Råheim et al. 1979). This was interpreted as probably representing a deformational and low-grade metamorphic event; and, thus, a minimum age for emplacement of the pluton.

Petrography and geochemistry

The granodiorite at the sampled locality, c.500 m southeast of the lake Møklevatnet (UTM 8765/5390, map-sheet 1823 IV Grong) is medium grained (2-5 mm), weakly foliated and pinkish-grey to greenish-grey in colour. It is generally equigranular, although some feldspars reach up to 8 mm in size. Plagioclase (oligoclase,c.An_{25}), quartz and K-feldspar are the major minerals, the plagioclase showing moderately advanced saussuritisation. Accessory phases

Table 1. Major elements (wt.%), some trace elements (ppm, except Sr and Ba in wt.%) and CIPW norms for the granodiorite sample from near Møklevatnet.

SiO_2	Al_2O_3	TiO_2	FeO	Fe_2O_3	MgO
64.84	17.01	.36	.57	2.42	.89
CaO	Na_2O	K_2O	MnO	P_2O_5	
3.73	5.09	2.81	.08	.14	

Nb	Zr	Y	Sr	Rb	V	Ba
7	138	16	.14	77	48	.12

q	or	ab	an	di	hy	mt	hm	il	ap
16.2	16.6	43.1	15.3	1.2	1.7	1.1	1.7	.7	.3

are epidote, hornblende, biotite, zircon, sphene, apatite, chlorite and opaques. The green coloration stems from epidotisation, noted first by Gale (1975).

A c.1 kg specimen taken from the c.50 kg of sample material collected from the Møklevatnet locality has been analysed for major and trace elements. The sample was broken into small pieces before crushing, to ensure that there were no xenoliths present. Of the major elements, the high Al_2O_3 and Na_2O, and low MgO (Table 1) stand out in relation to values for average granodiorites (Hatch et al.1951). Another characteristic is that of high contents

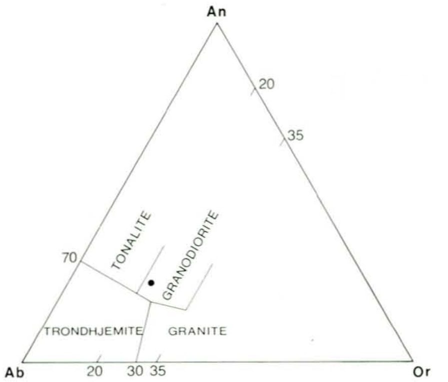

Fig. 2. Normative An-Ab-Or diagram showing the composition of the Møklevatnet granodiorite from the sample locality. Diagram from Barker (1979).

of Sr and Ba, which is a feature common to a number of calc-alkaline plutons elsewhere in the Norwegian Caledonides (Nordgulen et al. 1988). On a plot of normative Or, Ab and An (modified by Barker (1979) from O'Connor (1965)), the Møklevatnet pluton falls in the granodiorite field (Fig. 2); this is a trait confirmed by other diagrams. On a normative quartz-orthoclase-albite diagram, not shown here, the sample falls close to the calc-alkaline trend line.

Analytical methods and results

Mineral separation was performed using conventional magnetic- and density-separation procedures. Zircon fractions were prepared by hand-picking generally clear, crack-free grains, and abrading them after the method of Krogh (1982) to increase the degree of concordancy. Zircon dissolution, spiking with an enriched ^{205}Pb-^{235}U tracer solution, and separation of U and Pb for mass spectrometric analysis followed the method of Krogh (1973). The isotopes of U and Pb were purified, eluted and loaded together on a Re filament with Si-gel and H_3PO_4 and measured in a VG 354 mass spectrometer in the temperature range 1500° - 1630°C with each run lasting approximately 2 hours.

Zircon analyses were corrected for U blanks of 1-2 pg and Pb blanks of 10 pg or less; any remaining common-Pb was assumed to have the isotopic composition given by the model of Stacey & Kramers (1975) at the measured age of the rock. Total common-Pb abundances range between 10.5 and 13.1 pg and measured $^{206}Pb/^{204}Pb$ ratios range between 30,914 and 12,960 (Table 2), indicating that the uncertainty in the initial common-Pb composition has a negligible effect upon the age calculation.

Further details regarding the chemical, mass spectrometric and data reduction procedures are summarised in Tucker et al. (1991). Decay constants and isotope abundance ratios are those of Jaffey et al. (1971), recommended by the International Union of Geological Sciences (IUGS) (Steiger & Jäger 1977). Cited ages are the average $^{207}Pb/^{206}Pb$ ages and, because all analyses are concordant, the uncertainty of the age was obtained by estimating that position of concordia which is overlapped significantly by the error ellipses (Fig.3, calculated after the method of Ludwig 1980). Age errors are given at the 95% confidence level.

Three multigrain fractions of coarse (>200 µm) short-prismatic zircon were selected for isotopic analysis, including tips broken from prismatic grains, middle parts of prismatic grains, and whoie short-prismatic grains. These parts were selected and analysed separately to test for the presence or absence of inherited zircon which is known to be a common component in short-prismatic zircon populations. No inheritance (or secondary Pb-loss) is indicated by the results, however, as all

Table 2. U-Pb zircon data.

Fraction	wt. (µg)	U (ppm)	Pb comm. (pg)	Pb rad. (ppm)	Th/U	206Pb/ 204Pb	206Pb/ 238U	207Pb/ 235U	207Pb/ 206Pb	207Pb/ 206Pb (Ma)
1 + 100,t-p,A	118	378	11.9	29.7	.58	17,157	.07335±28	0.5678±23	.05614±8	457.9
2 - 200,s-p,A	100	371	13.1	29.3	.61	12,960	.07326±30	0.5663±25	.05607±9	454.9
3 + 100,mp,A	254	281	10.5	22.1	.60	30,914	.07311±26	0.5656±21	.05611±8	456.7

The zircons are clear, transparent grains, from least paramagnetic fractions of Frantz separates, free of cracks and inclusions unless otherwise specified. +100 = >150 µm, -200 = <75 µm; s-p = short-prismatic (length to width <3), mp = middle parts of prismatic (length to width >3) grains; t-p = tips from prismatic grains; A - abraded.

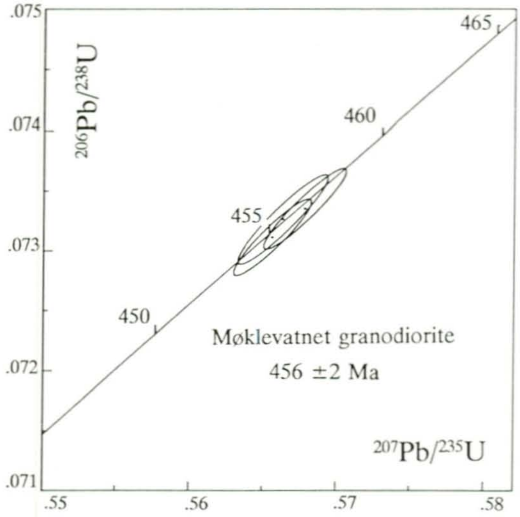

Fig.3. U-Pb concordia diagram of zircon analyses (1, 2, 3,Table 2) from the Møklevatnet granodiorite.

three analyses are concordant (Fig.3) indicating an emplacement age of the granodiorite of 456 ± 2 Ma.

Discussion

The age of 456 ± 2 Ma for the Møklevatnet granodiorite complements the reported U-Pb zircon date of 483 ± 4 Ma from an albite trondhjemite in the northern part of the Gjersvik Nappe (Kullerud et al.1988). The 483 Ma trondhjemite is located in the stratigraphically lower part of the magmatic assemblage (Lutro 1979). Field relationships show that the Møklevatnet granodiorite is the youngest major pluton within this nappe, and that in these southern areas we are close to the roof of the intrusion (Gale 1975). Moreover, Gale (1975), has described an erosional and weathering surface of the granodiorite in one area where the contact with the basal conglomerate of the Limingen Group is marked by «a few metres of a clastic 'trondhjemitic sediment' which..... contains abundant clastic feldspar and quartz». In other areas the basal part of the conglomerate consists largely of angular blocks of granodiorite.

Accepting that we have dated perhaps the youngest major member of the thick volcano-plutonic complex, then the evolution of this ensimatic arc- and rift-related assemblage (Gale & Roberts 1974, Halls et al. 1977, Reinsbakken 1980), tending towards calc-alkaline compositions higher up, has extended over a period of 25 to 30 million years, from c. Middle Arenig to Early Middle Caradoc (Tucker et al. 1990). Such a time span is comparable to that of island arc/basin systems in the western Pacific Ocean (Crawford et al. 1981).

The 456 ± 2 Ma age for the granodiorite can also be regarded as a maximum age for the sediments of the Limingen Group. The duration of the hiatus between magmatism and uplift, erosion and sedimentation is impossible to determine; yet one may infer this to have been comparatively short. Accepting a Middle Caradoc or younger age for the Limingen Group sediments makes them time equivalents of the uppermost parts of the Lower Hovin and succeeding Upper Hovin Groups of the western Trondheim region (Roberts 1975, Halls et al. 1977). The basal conglomerate of the Limingen Group may thus occupy a comparable stratigraphic position to that of the Stokkvola Conglomerate. Higher parts of the Kjølhaugen Group in the Meråker Nappe of eastern Trøndelag (Wolff 1979) may be chronostratigraphic equivalents of the Limingen Group. Another unit of likely similar age is the Blåsjö Phyllite in the Stikke Nappe in lower parts of the Middle Köli (Claesson et al. 1988).

Although no regional metamorphic event has been reported from the Gjersvik Nappe prior to Limingen Group deposition, Halls et al. (1977) have described features which they ascribe to pervasive sea-floor metamorphism. The penetrative foliation in the granodiorite and coplanar schistosity in the Limingen metasediments, on the other hand, are considered to date to the Scandian orogenesis.

This scenario differs somewhat from that in the adjacent Helgeland Nappe Complex (HNC), above and to the west of the Gjersvik Nappe. This exotic terrane has a history of igneous activity ranging from Late Cambrian to Early Silurian time, and includes a significant tectonothermal event, with thrusting, in the Ordovician (Nissen 1986, Nordgulen & Schouenborg 1990, Ø.Nordgulen pers.comm.1990) in addition to the later Scandian deformation and metamorphism. In the HNC the Heilhornet Pluton has yielded a U-Pb zircon age of 444 ±11 Ma (Nordgulen & Schouenborg 1990) which thus overlaps, within error, with the age of the Møklevatnet granodiorite. The initial Sr ratio of the Heilhornet granite (c.0.7070), however, is somewhat higher than that of the Møklevatnet body (0.70427; or 0.70414 minus the one gabbro sample). All in all, the geological development and structural histories of the Helgeland and Gjersvik Nappes indicate that these tectonic units represent disparate terranes.

Conclusions

The Møklevatnet pluton in the southern and tectonostratigraphically highest part of the Gjersvik Nappe is a granodiorite with a calc-alkaline signature. Three fractions of zircon chosen for U-Pb dating gave concordant analyses that indicate a crystallisation age of the granodiorite of 456 ± 2 Ma; i.e., Early-Middle Caradoc. This can be regarded as a maximum age for the oldest sediments of the unconformably overlying Limingen Group.

Magmatic activity in the Gjersvik Nappe covered a time span of some 25 to 30 million years. Unlike the situation in the suprajacent HNC, no evidence has been reported in the Gjersvik Nappe of any significant tectonothermal activity in the Ordovician. These two juxtaposed nappes would thus represent disparate terranes, with different histories of geological and tectonometamorphic development, brought together during Scandian continent-continent collision.

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