Geology, geochemistry and age of the 'Tricolor' granite and some other Proterozoic (TIB) granitoids at Trysil, southeast Norway

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The Trysil granitoids of southeast Norway constitute a relatively undeformed element in the northern part of the late Palaeoproterozoic Transscandinavian Igneous Belt (TIB) exposed southeast of the Scandinavian Caledonides. In the Trysil–Engerdal area younger granites intruded foliated granitoids (ca. 1800 Ma older Värmland type) and lower parts of the Dala/Trysil volcanic rocks. Two main types of younger granite are distinguished. The traditional 'Tricolor' granite with pink K-feldspar, bluish quartz, greenish plagioclase and dark patches of biotite probably intruded an amphibole-bearing, mesoperthitic granite. Both varieties are I-type granites, generated in a within-plate tectonic setting. They have similar trace and major element geochemistry, and their Nd isotopes indicate a source characteristic of a depleted mantle component and a short crustal residence time. According to U-Pb dating of zircons, the 'Tricolor' granite intruded 1673 ± 8 Ma ago. A somewhat younger Rb-Sr age of 1642 ± 35 Ma has been obtained from six whole-rock samples of the two granites. The younger Trysil granites can be correlated in age and tectonic setting with the post-volcanic Dala (e.g. Garberg) and Rätan granites further east in the Swedish part of the TIB. It is conceivable that this type of granitoid (e.g. the Odalen granite) extends westwards into the Southwest Scandinavian Domain as far as the Mylonite Zone, with an increasing influence from Sveconorwegian events.

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Introduction

Most of southwest Fennoscandia was accreted to the Baltic Shield during Palaeo- and Mesoproterozoic times. Tectonically, and with respect to age, the region is subdivided into several domains (inset map in Fig. 1). According to Gaál & Gorbatschev (1987) these include, from northeast to southwest, the Svecofennian Domain, the Transscandinavian Igneous Belt (TIB) and the Southwest Scandinavian Domain (SSD). The last domain shows extensive overprint by both the Gothian/Kongsbergian (1.75–1.5 Ga) and Sveconorwegian (1.25–0.9 Ga) orogenies (Lindh 1987; Starmer 1993). To the east, the SSD terminates in an easternmost belt of polyphase Palaeo- to Mesoproterozoic shearing and faulting, traditionally known as the 'Protogine Zone' (e.g. Larson et al. 1990), or in the somewhat further eastward-extending Sveconorwegian Frontal Deformation Zone of Wahlgren et al. (1994). In contrast to the SSD, the major part of the TIB (1.8–1.6 Ga) and the Svecofennian Domain (2.0–1.8 Ga) are only weakly, or not at all affected by the Sveconorwegian orogeny. Primary relationships with respect to Gothian and Svecofennian events are therefore well preserved.

Geology and age relations within the TIB are well established in the Swedish areas of Dalarna, Värmland and Småland (for a summary, see Lindström et al. 1991). The volcanic rocks have traditionally been divided into the Lower and Upper Dala 'Series' (Hjelmqvist 1966) with associated pre-, syn- and post-volcanic syenitoid to granitoid intrusions. Recent age datings indicate that oldest rocks within the TIB may represent xenolithic complexes with Svecofennian affinity (Patchett et al. 1987; Jarl & Johansson 1988; Persson & Lundqvist 1993; Welin 1992; Lindström et al. 1991). A general pattern of westward younging events of crust formation across the TIB has been suggested by Larson & Berglund (1992) and Lindh (1987).

The granitoid rocks described here are located in the western, Norwegian part of the TIB. The investigation is focused on the geological setting, chemistry and age of the younger Trysil granites in the easternmost Proterozoic basement of southern Norway. One of the granites, the traditional 'Tricolor' granite, has been known since the earliest 'geognostic' survey of Norway (see below).

The investigation is part of a regional mapping programme carried out by the Geological Survey of Norway (NGU) including two of the authors (M. H. and F. W.). The results of detailed fieldwork have been presented by Nystuen (1975 and 1976) and Heim (1989) and the regional aspects by Wolff et al. (1995).

Regional setting

The Trysil–Engerdal area is situated in the easternmost part of southern Norway, geographically forming a lobe

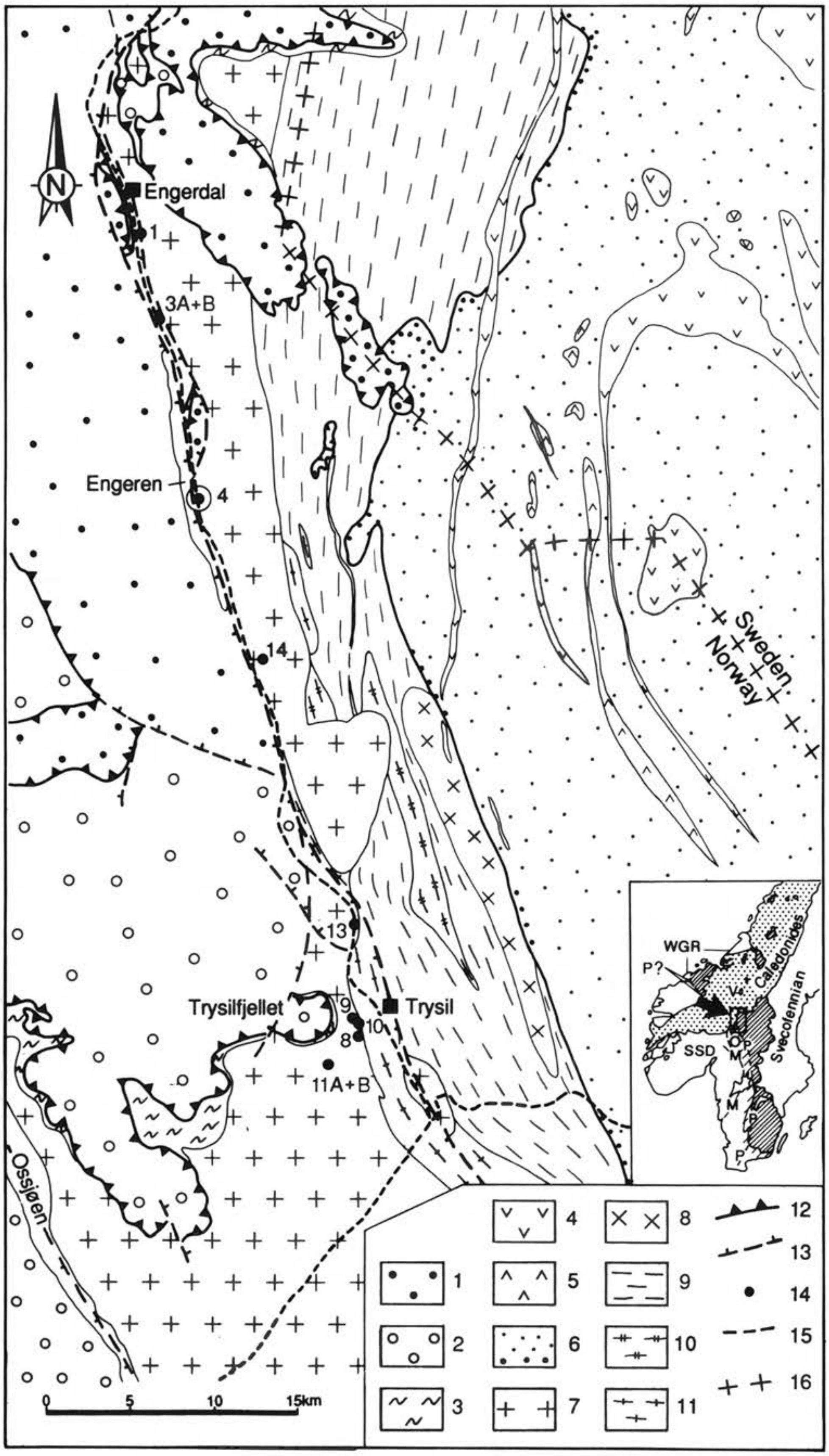

Fig. 1. Geological sketch map of the Trysil–Engerdal area with sample localities (modified after Siedlecka et al. 1987 and Wolff et al. 1995). Caledonian units: **1.** Kvitvola Nappe; **2.** Osen-Røa Nappe; **3.** Cambro–Ordovician cover (autochthon). Jotnian units: **4.** basic dyke/sill; **5.** basalt (Öje Basalt); **6.** Trysil and Dala sandstone with basal conglomerate. Transscandinavian Igneous Belt: **7.** Trysil granitoids (younger Dala/Värmland granitoids); **8.** quartz syenite; **9.** Trysil/Dala porphyry; **10.** greenstone/metabasalt; **11.** Older Dala/Värmland granitoids. Symbols; **12.** Caledonian thrust fault; **13.** Post-Caledonian normal fault (Permian in part); **14.** sample site with number (4: U-Pb sample); **15.** main-road; **16.** national border. Inset map after Larson & Berglund (1992) and Tucker et al. (1990): Ruled: Transscandinavian Igneous Belt (TIB) with possible westward extension (spaced ruling). SSD: Southwest Scandinavian Domain. WGR = The Western Gneiss Region. M = The Mylonite zone. P = The Protogine Zone. O = Odalen. V = Vigelen. Area of investigation marked with arrow.

into the Dalarna and Värmland areas of Sweden (see map Fig. 1). The geology of the Engerdalen area was described by Holtedahl (1921) and essential areas around Trysil by Heim (1989). The Proterozoic basement consists of predominating acid volcanic and intrusive rocks of the westernmost TIB (Dala/Trysil porphyry and Dala/Värmland/Trysil granitoids) with an unconformable Jotnian (i.e. post-Gothian, 1.5–1.25 Ga) cover of as much as 1000 m sandstone (Trysil and Dala sandstone) including a basalt flow (Öje basalt). The Jotnian rocks constitute the western part of an open synclinal basin. The Sveconorwegian influence on this supracrustal cover is restricted to the formation of open large-scale folds and a locally developed 'fracture cleavage' (Heim 1989). Primary relations are therefore well preserved within the TIB and between the TIB and the Jotnian cover (Hjelmqvist 1966; Wolff et al. 1995). TIB intrusive rocks can be divided into older, weakly to moderately foliated, and younger, massive granitoids. A general correlation of the Trysil granitoids with older and younger Värmland/Dala granitoids, respectively (Larson & Berglund 1992) is discussed below.

West and northwest of Trysil the Precambrian basement is nonconformably overlain by miogeoclinal Caledonian sequences. Neoproterozoic arenites of the Lower and Middle Allochthon, thrust on a thin, autochthonous Cambro–Ordovician cover, are the dominating lithologies (Bockelie & Nystuen 1985). Along the main valley between Trysil and Engerdal, the boundary between basement and Caledonian cover is affected by a prominent fault zone with vertical offset (west-side down) locally exceeding 1000 m. In the basement around Trysil the fault zone appears to have a polyphase, in part Precambrian (probably Sveconorwegian) history (Heim 1989). Major activity, however, occurred in post-Caledonian time, mainly during the Permian, forming the Engerdalen fault (Bockelie & Nystuen 1985), characterized by cataclasites and quartz-cemented fault breccias.

Petrography of some Trysil granitoids

Field investigation has revealed a series of different types of mainly granitoid intrusive rocks. The most common type corresponds to what traditionally has been called 'Tricolor' granite ('granit trikolor'). According to Holtedahl (1953, p. 59) this name was introduced by Kjerulf in the Vigelen area, 140 km north of Trysil, for the red-, blue- and green-coloured, massive granite common in the region. An early description of this granite from the Trysil area was given by Keilhau (1840), who thought it was older than the Caledonian cover. Because of its fresh appearance, Kjerulf (1879) and Meinich (1881) compared the granite with the 'younger granites' in the Oslo Region and described intrusive contacts with the Caledonian arenites. Törnebohm (1896) and Reusch (1914) definitely established a pre-Caledonian age for the Trysil granites.

Trysil granitoids have been sampled in the narrow zone between the Caledonian cover and the Trysil porphyries, close to the main valley between Trysil and Engerdal. Sample localities (Fig. 1) are spread over a north–south distance of about 50 km. The sample for the U-Pb age determination was collected at locality 4, a road-cut (national road no. 26) on the eastern shore of Lake Engeren (sample localities are described in the Appendix).

Age relationships between different intrusions and between intrusive and volcanic rocks are not fully understood, but a division into older, partly foliated pre- to syn-volcanic granitoids and younger, massive, post-volcanic granitoids has been established. All the types described below, apart from the granodiorite, are likely to belong to the younger granitoids. Modal compositions are presented in Table 1.

'Tricolor' granite

This granite covers large parts of the investigated area and corresponds to the traditional 'Tricolor' granite. The samples (1, 4, 11A and 14), taken from localities up to 25 km apart, show little variation in mineralogical composition and texture. The 'Tricolor' granite is characterized by pinkish K-feldspar, bluish quartz, greenish, moderately saussuritized plagioclase and dark patches of biotite. The rock has a medium- to coarse-grained (3–7 mm), granular texture with scattered poikilitic microcline of up to 15 mm (Fig. 2).

Typical microfeatures are perthitic (band and patch perthite), anhedral microcline, subhedral quartz, partially

Table 1. Modal composition of selected Trysil granitoids. Determination by point counting of thin-sections (3.5 × 2 cm). For sample localities, see Fig. 1 and the Appendix.

	Trysil 'Tricolor' granite				Dyke	Perthite granite				Other rocks	
	TR-4	TR-14	TR-1	TR-11A	TR-3B	TR-10	TR-8	TR-9	TR-11B	TR-13	TR-3A
Quartz	25.0	32.0	25.6	30.0	32.2	23.5	23.9	24.6	29.7	20.9	13.9
K-feldspar	45.9	49.6	44.5	39.1	45.0					18.3	5.6
(Meso-)perthite						63.1	63.2	66.6	58.3		
Plagioclase	19.8	16.0	25.5	23.7	16.8	10.7	9.7	6.3	9.4	48.9	65.8
Biotite	6.9	1.8	2.7	6.4	4.1	1.0	1.0	1.3	1.3	6.7	6.2
Amphibole						1.1	1.6	0.1	0.6	2.5	7.3
Sphene	1.0	0.4	0.8	0.5	0.7	0.3	0.3	0.4	0.2	0.8	0.6
Opaque minerals	0.8	0.1	0.2	0.1	1.1	0.3	0.2	0.6	0.5	1.2	0.6

Fig. 2. Thin-section view of the Trysil 'Tricolor' granite. Granular texture, slightly disturbed by shear vein in left part of picture. See text for description. Minerals shown are: qz = quartz, mi = microcline, pl = plagioclase, bi = biotite, ep = epidote, sp = sphene, al = allanite, zr = zircon, st = stilpnomelane, op = opaques.

altered oligoclase (An < 18%) and subhedral, olive-green biotite. Early, sub- to euhedral phases include sphene, apatite, allanite and zircon. Zircon commonly forms inclusions in biotite, surrounded by pleochroic haloes caused by radioactive decay of the mineral. Fine-grained aggregates of secondary, green biotite, epidote and opaque phases possibly represent pseudomorphs after primary amphibole (hornblende).

The following sequence of crystallization can tentatively be given:

accessories ⇒ biotite (+amphibole?) ⇒ oligoclase ⇒

quartz (⇐) ⇒ microcline

Though most sample localities are situated relatively close to the Engerdalen fault, the rocks show comparatively little influence by semiductile and brittle deformation. Deformation appears to be concentrated in thin shear veins and bands, characterized by dynamically recrystallized quartz, cataclastic granulation of feldspar and formation of fine-grained secondary material, including granular epidote (see Fig. 2). Fibrous aggregates of strongly pleochroic stilpnomelane are another typical feature.

(Meso-)perthite granite

Samples of this granite type (8, 9, 10, 11B) were collected to the east and south of Trysilfjellet (Fig. 1). No contacts with the 'Tricolor' granite have been observed, but a fine- to medium-grained granite (sample 11A) may represent a dyke or minor intrusion of 'Tricolor' granite within an area dominated by perthite granite, indicating an older age for the latter.

The perthite granite is medium- to coarse-grained (3–10 mm) with dominating pink to orange-grey alkali feldspar, blue-grey quartz, scattered phenocrysts of green-grey plagioclase (< 1.2 cm) and minor amounts of dark biotite and amphibole. The rock has an inequigranular texture with feldspar having largest grain size. Perthitic (braid and band) to mesoperthitic alkali feldspar, usually with albitic rim, is characteristic. Carlsbad twins are common. Phenocrysts of albitic plagioclase are mantled by perthite. Quartz is anhedral, locally subhedral. Strongly pleochroic biotite and amphibole (ferrohastingsite?), up to 1.5 mm, form patches together with accessory minerals including sphene, apatite and zircon. Stilpnomelane is a common secondary mineral.

The tentative crystallization sequence is:

accessories ⇒ amphibole and biotite ⇒ plagioclase ⇒

(meso-)perthite (⇐) ⇒ quartz

Granodiorite and quartz diorite

At locality 3 fine-grained granitic dykes, texturally and mineralogically similar to the 'Tricolor' granite (sample TR-3B), intrude medium-grained biotite-hornblende quartz diorite (sample TR-3A). Sample TR-13 (locality

13) has an inequigranular to feldspar-porphyritic texture and a composition of a hornblende-bearing biotite granodiorite. In both samples, oligoclase (An 20–30) is the dominating feldspar and primary biotite and hornblende are essential constituents (see Table 1). From the intrusive relationships at locality 3, described above, these intermediate rocks appear to be older than the 'Tricolor' granite. Their relationship to the perthite granite is not clear, however, since no contacts are observed.

Geochemistry

Six samples were selected for chemical analysis of major elements and 31 trace elements. All elements with the exception of Sm, Nd, Rb and Sr (see below), were analysed by XRF at the laboratory of NGU (Geological Survey of Norway) in Trondheim by standard methods. The results are listed in Table 2. Some of the trace element values were below the limit of detection for all samples (with exceptions) and are not listed. This concerns: S, Cl and F (TR-14 = 0.12) below 0.1%; W below 30 ppm; U, Sc, Sb, Sn, Cd, Ag, Co and As all below 10 ppm; Ni, Cr, Mo (TR-4 = 6, TR-10 = 7) and Cu (TR-3B = 41) below 5 ppm.

The analysed rocks show very similar chemical composition. There are no significant compositional differences between the 'Tricolor' granite and the perthite granite. In the total alkali versus silica diagrams (not shown), all samples plot within the 'rhyolite' field (Cox et al. 1979), and in the sub-alkaline (silica oversaturated) part of the diagram (Irvine & Baragar 1971). Discrimination in a Zr/TiO_2 versus Nb/Y diagram of Winchester & Floyd (1977) (Fig. 3a) places five samples within the rhyolite field, one sample (11A) in the neighbouring rhyodacite field. In the K–Na discriminating diagram (not shown) of Chappell & White (1974), all samples, with the exception of TR-3B show I-type character. The higher K/Na-ratio of this dyke could be explained either by magmatic differentiation or by assimilation processes while intruding the quartz diorite. Moreover, the dyke is the only rock with a measurable Cu content (41 ppm), supporting the idea of assimilation of basic host rock. Pearce et al. (1984) used trace-element diagrams for tectonic classification of granitoids. In the Rb versus Y + Nb diagram (Fig. 3b) the samples plot in the upper left corner of the

Table 2. Geochemical analyses of six Trysil granites. Major elements in percent, trace elements in ppm. * and ** under limit of detection (5 ppm, 10 ppm resp.). Rubidium, strontium, samarium and neodymium isotopic data. $(^{87}Sr/^{86}Sr)_0$ and ε-Nd (CHUR-normalized) are calculated assuming an age of 1673 Ma.

	Trysil 'Tricolor' granite			Dyke	Perthite granite	
	TR-4	TR-14	TR-11A	TR-3B	TR-10	TR-11B
SiO_2	70.52	71.50	70.25	71.96	69.89	70.85
TiO_2	0.38	0.26	0.40	0.37	0.43	0.37
Al_2O_3	14.08	13.94	14.38	13.10	14.36	13.81
Fe_2O_3	2.52	1.83	2.37	2.45	2.71	2.42
MnO	0.07	0.06	0.09	0.05	0.12	0.10
MgO	0.45	0.21	0.44	0.24	0.30	0.27
CaO	1.28	0.90	1.30	0.86	0.93	0.69
Na_2O	3.81	4.07	4.31	2.64	4.41	4.11
K_2O	5.50	5.54	4.86	6.79	5.74	5.77
P_2O_5	0.09	0.05	0.08	0.04	0.07	0.06
LOI	0.37	0.39	0.47	0.30	0.37	0.46
Total	99.07	98.75	98.95	98.80	99.33	98.91
V	22	11	15	11	23	15
Cu	*	*	*	41	*	*
Zn	51	53	67	55	49	72
Ga	15	19	17	16	13	18
Rb	188	217	146	185	135	137
Sr	157	86	189	112	81	78
Ba	834	520	1335	792	844	602
Y	38	72	48	63	41	56
Zr	309	293	321	450	322	373
Nb	24	33	16	25	22	20
La	67	66	48	88	72	113
Ce	123	133	103	153	124	190
Sm	8.3	11.8	8.3	14.2	13.5	14.0
Nd	49.4	65.2	46.8	80.0	79.2	90.9
Pb	18	20	16	21	19	14
Th	**	**	11	13	**	12
$^{87}Rb/^{86}Sr$	3.488	7.450	2.248	4.819	4.861	5.155
$^{87}Sr/^{86}Sr$ (±6)	0.78636	0.88144	0.75711	0.81535	0.81895	0.82573
$(^{87}Sr/^{86}Sr)_0$	0.70250	0.70234	0.70307	0.69949	0.70210	0.70180
$^{147}Sm/^{144}Nd$	0.1018	0.1100	0.1077	0.1078	0.1040	0.0939
$^{143}Nd/^{144}Nd$ (±14)	0.511656	0.511747	0.511697	0.511739	0.511668	0.511570
ε-Nd (±.15)	1.03	1.05	0.57	1.37	0.79	1.06

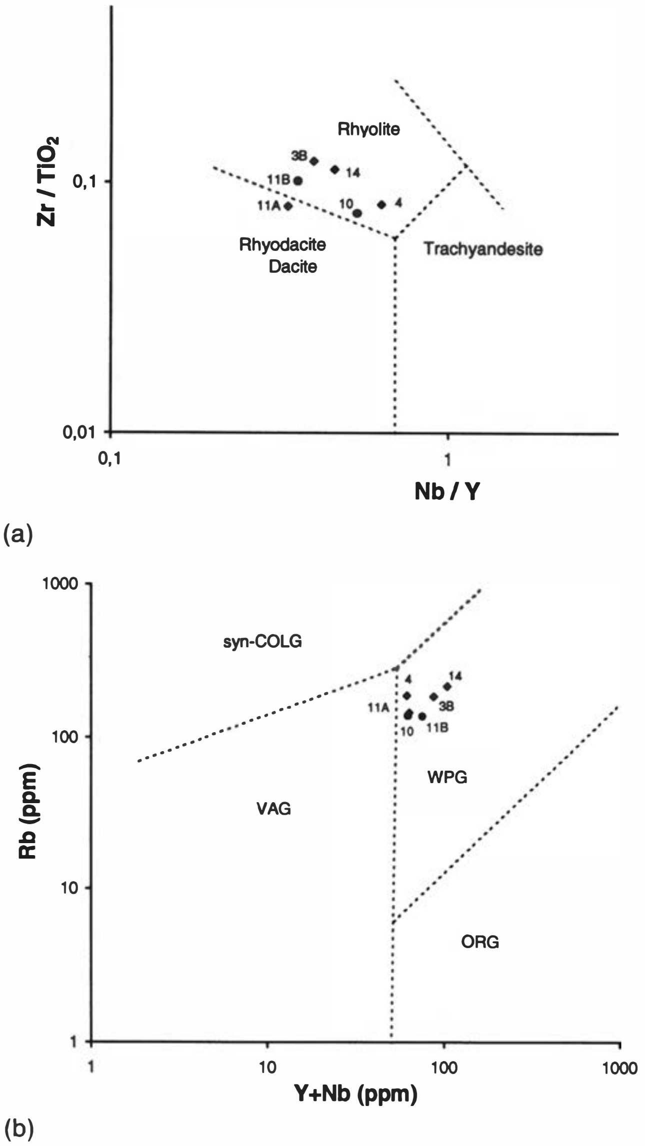

Fig. 3. Geochemical discrimination diagrams of six Trysil granites. Squares = 'Tricolor' granite; filled circles = perthite granite. Sample numbers according to Table 1. (a) Nb/Y vs. Zr/TiO_2 diagram according to Winchester & Floyd (1977). (b) Rb vs. Y + Nb diagram (ppm). Subdivision according to Pearce et al. (1984). VAG = volcanic arc granite, ORG = ocean ridge granite, WPG = within plate granite, syn-COLG = syn-collision granite.

within-plate field, three of the samples being close to the volcanic arc field.

Isotope analyses and age

U-Pb isotope analysis on zircons from the 'Tricolor, granite

Zircons from a rock sample of the 'Tricolor' granite from locality 4 were dated by one of the authors (T.S.) at the Laboratory for Isotope Geology of the Swedish Museum of Natural History (Stockholm).

Description of the zircons. – Foreign isotropic inclusions are abundant in the zircons of the 'Tricolor' granite. Only zircons with the least magnetic or non-magnetic properties were of the kind considered suitable for dating, i.e. without detectable inclusions or obvious cores and with the transparency of crystals almost devoid of fractures. In general, the zircons are somewhat brownish and short-prismatic with length to width ratios of about 2:1. The prisms are sub-quadratic to rectangular in a plane perpendicular to the c-axis and the development of [hkl = 110] compared to that of [100] is minor which makes the terminations almost perfect pyramids [101]. In the classification scheme of Pupin (1980) most of the zircons resemble type S25 and are considered to reflect high temperature crystallization.

Of the eight zircon fractions analysed, two have been abraded/polished following the technique described by Krogh (1982). The reason for abrading the crystals is twofold: (i) to improve the degree of concordancy in the U/Pb isotope diagram by removing damaged parts of the crystals, and (ii) to reveal potential multi-stage zircon crystallization, i.e. zones of complex crystallization that have taken place at distinctly different times.

Analytical technique and discussion of isotope data. – The number of crystals used for each zircon analysis ranges from 35 to 70, which allows for a relatively rigorous selection of those dissolved for analysis. At the time of sample preparation (autumn 1992) our total-lead blank level was in the range of 30 pico-grams with occasional higher values. This blank includes sample dissolution in 1 inch diameter teflon 'Krogh'-capsules, hydrochloric ion exchange procedure using 50 μl resin and sample loading on Re filament with silica gel and phosphoric acid. Lead was spiked with synthetic lead 205-tracer and measured in static mode with a Finnegan MAT 261 multicollector mass spectrometer. The analytical data are presented in Table 3.

A regression analysis (Fig. 4), according to Ludwig (1991a, b), of the eight zircon fractions resulted in a discordia line which intersects the concordia at 1672.7 ± 7.7 and 34 Ma. The MSWD value of 1.4 indicates an acceptable fitness of the data to the discordia line. This age is close to the $^{207}Pb/^{206}Pb$ model age of the most concordant fraction, which for cases of single-stage crystallization is reassuring. Because of the good correlation to the discordia, of not only the unabraded, but also the abraded zircons, it can be concluded that secondary metamorphic overgrowth and inherited zircon cores are non-existent or of negligible importance. Thus the age of 1673 ± 8 Ma is considered to date the time of primary zircon crystallization which is suggested to approximate the time of granite emplacement.

Rb-Sr and Sm-Nd isotope data

An Rb-Sr and Sm-Nd element and isotope whole-rock analysis was carried out at the Mineralogical–Geological Museum in Oslo, using the same samples that were

Table 3. U-Pb analytical data of the 'Tricolor' granite.

Fraction[a] (μm)	Weight (μg)	Concentration U (ppm)	Concentration Pb_{rad} (ppm)	$^{206}Pb/^{204}Pb$	Radiogenic (at.%)[b] ^{206}Pb	^{207}Pb	^{208}Pb	Isotopic ratios $^{206}Pb/^{238}U$	±2σ	$^{207}Pb/^{235}U$	±2σ	Age (Ma) $^{207}Pb/^{206}Pb$	±2σ
A Mag 1°, >106, 50xx	171	168	32.9	1430	79.25	8.06	12.69	0.1806	0.0005	2.531	0.023	1654	15
B Mag 1°, >106, 50xx, Abr	222	106	30.0	3840	79.16	8.09	12.75	0.2593	0.0006	3.655	0.018	1665	7
C Mag 1°, <106, 45xx, Abr	74	199	50.8	179	78.19	8.04	13.77	0.2323	0.0006	3.292	0.023	1675	11
D Mag 1°, <106, 35xx	61	170	51.3	858	78.33	8.01	13.66	0.2752	0.0009	3.877	0.044	1664	18
E NM, >106, 40xx	150	114	38.0	125	72.57	7.45	19.98	0.2805	0.0007	3.973	0.057	1674	23
G NM, 74-106, 70xx	104	139	38.8	1000	76.55	8.65	14.80	0.2539	0.0007	3.585	0.025	1669	11
H NM, >106, 42xx, br	195	129	34.5	1200	78.01	8.06	13.93	0.2436	0.0006	3.469	0.036	1684	17
I NM, <74, 40xx, br	58	120	31.4	380	77.71	8.01	14.28	0.2369	0.0011	3.365	0.058	1679	28

[a] Affiliations: Mag 1° = magnetic at 1° sideward inclination and 1.6 A with Franz isodynamic magnet separator; NM = non-magnetic; 40xx = 40 zircon crystals analysed; Abr = abraded crystals; br = brownish.
[b] Corrected for lead blank (30 pico-grams) and common lead according to Stacey & Kramers (1975).

analysed for major and trace elements. The analytical procedures have been described by Mearns (1986). Isotope ratios and Sm, Nd and Sr element concentrations were measured on a fully automated 5 collector VG 345 mass spectrometer. Rb was analysed on a VG Micromass 30.

The Rb-Sr data are listed in Table 2 and the relevant isotopic ratios have been plotted in Fig. 5. The data satisfy an age of 1642 ± 35 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.70391 ± 97, MSWD = 1.31. The absolute age is lower but within error of the U-Pb zircon age. With the exception of the dyke (sample TR-3B), the initial Sr isotope ratios are between 0.7018 and 0.7031 (Table 2) when recalculated to the zircon age.

The Sm-Nd data (Table 2) yield a best-fit 'isochron' of 1657 ± 360 Ma. Despite the high error bar, due to limited variation of the values, the age is in accordance with those obtained by the other methods. A plot of initial ε-Nd values versus initial $^{87}Sr/^{86}Sr$, based on the 1673 Ma zircon age, is shown in Fig. 6. All initial ε-Nd values are positive (+0.6 to 1.4).

Discussion

Geochemistry and isotope characteristics support the close connection between the 'Tricolor' and the (meso-)perthite granites proposed on field observations and mineralogy. Both types have a rather low water content (little hydrous minerals) indicating comparably high crystallization temperatures and favouring the formation of mixed feldspar crystals (e.g. Tuttle & Bowen 1958).

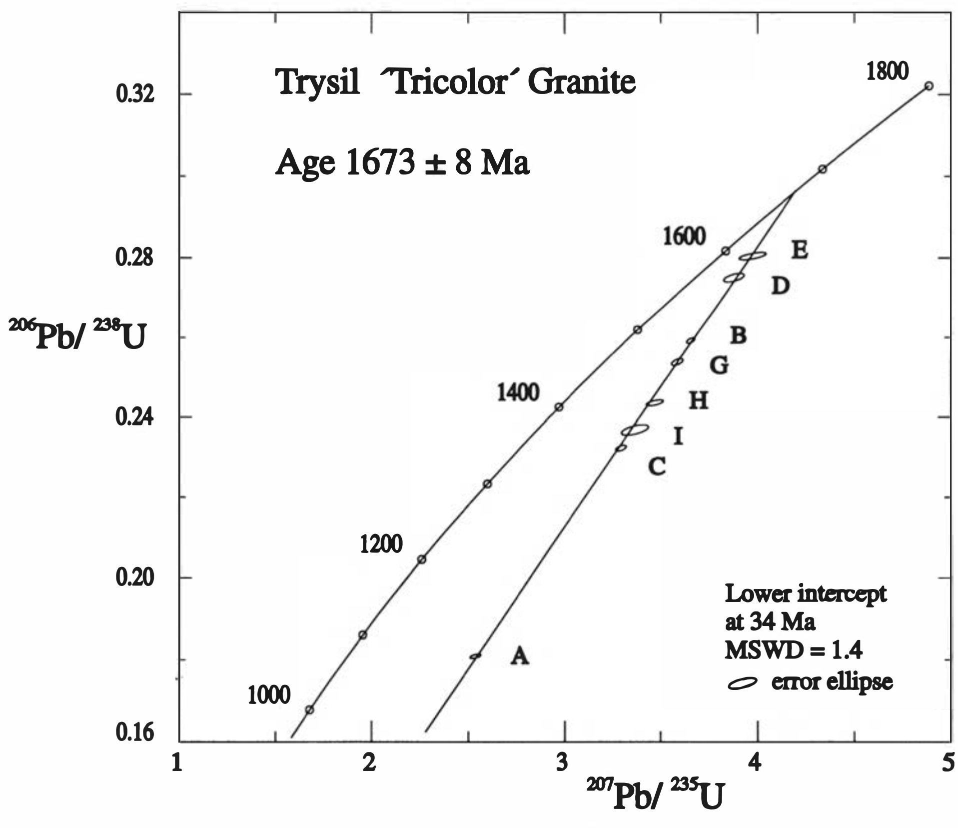

Fig. 4. U-Pb concordia plot of zircons from the 'Tricolor' granite (sample Tr-4). The zircon fractions are assigned in accordance with Table 3.

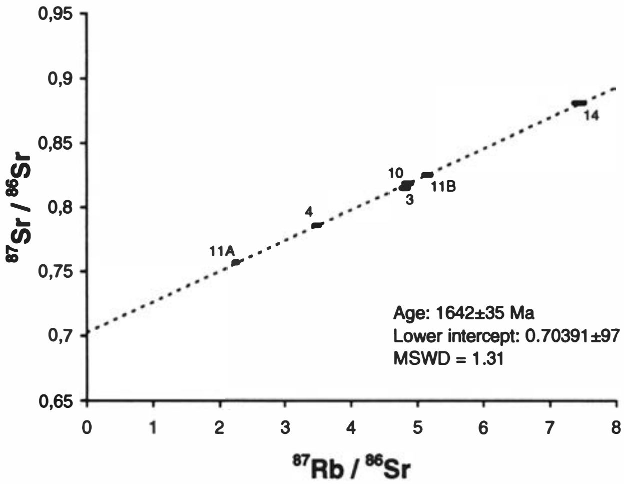

Fig. 5. Rb-Sr diagram for six Trysil granite whole-rock samples. Error bars numbered as in Table 2.

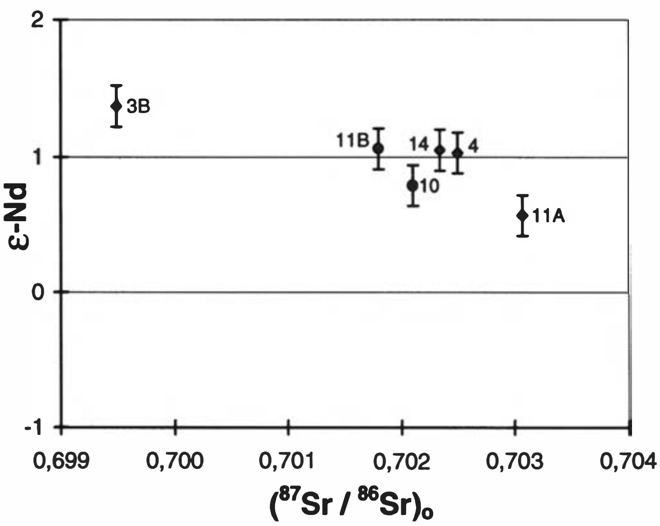

Fig. 6. ε-Nd versus ($^{87}Sr/^{86}Sr$)$_0$ diagram for six Trysil granites. Symbols and numbers as in Fig. 3.

The observed differences in feldspar mineralogy can thus be explained by the dryer character of the perthitic type compared to the 'Tricolor' type (see Table 1). Alternatively, with comparable water content, crystallization at shallow level would increase the stability field of perthitic feldspars. A late-crystallization rise of the 'Tricolor' type would then be needed to explain the juxtaposition of the granites.

From the Swedish part of the TIB, granites with petrography and major element chemistry comparable to the Trysil granites were described by Hjelmqvist (1966). Of the Dala granites, both the Siljan granite and the Dala-Järna granite resemble the 'Tricolor' granite. A mesoperthitic granite, similar to the one described above, is found in the Garberg-type Dala granite which, according to Hjelmqvist (op. cit.), intrudes the youngest Dala volcanic rocks.

A number of U-Pb zircon ages of nearby granites compare well with the 1673 ± 8 Ma age obtained in this study. The Garberg granite has an age of 1680 ± 6 Ma (sample SW-66 of Patchett et al. 1987) which is also similar to the 1698 ± 22 Ma (Wilson et al. 1985) and 1679 ± 58 Ma (sample SW-58 of Patchett et al. 1987) ages of the K-feldspar-porphyritic Rätan granite which forms large, composite intrusions in the northern part of the TIB. Larson & Berglund (1992) suggested a threefold subdivision of the Dala magmatic history, according to which a first volcanic/plutonic episode (TIB 1) at 1.81 to 1.76 Ga is followed by a younger, volcanic/plutonic episode (TIB 2) at 1.71 to 1.69 Ga and youngest, post-volcanic plutonic rocks (TIB 3) at 1.68 to 1.65 Ga, the latter restricted to the western part of the TIB. The age and field relations discussed here would place the younger Trysil granites, including the 'Tricolor' granite, in the TIB 3 magmatic episode.

The scatter of the Trysil granite samples within the WPG field (Fig. 3b) is comparable to that of the Syke suite from Scotland, for which a rather depleted mantle source is invoked (Pearce et al. 1984). This suggestion is confirmed by the positive initial ε-Nd values between +0.6 and +1.4 (Fig. 6), values in accordance with those expected for I-type granites with a dominating depleted-mantle component (McCulloch & Chappell 1981) and similar to the values for other TIB granites, incl. Rätan and Dala granites (Patchett et al. 1987). Major contamination with older (Archaean) crust can therefore be excluded. A mantle-crust differentiation period at about 1.9 Ga may have been responsible for major formation of mantle-derived magma, although components from 1.7 Ga magmatism cannot be excluded (Wilson et al. 1985; Patchett et al. 1987). The proposed predominance of a mantle-derived component and a short crustal residence time for source rocks of the Trysil granitoids is likewise indicated by the low initial $^{87}Sr/^{86}Sr$ ratios (Table 2) and the comparatively low U- and Th-values found by Killeen & Heier (1975).

Granites with field characteristics of the 'Tricolor' granite are, as mentioned above, not restricted to the Trysil–Engerdal area, but appear as distant as the Vigelen area, 140 km to the north, and the Odalen area, 100 km to the south–southwest of Trysil (see inset map, Fig. 1). A major regional implication is that these comparatively young TIB 3 granitoids may well extend west of the mega-shear called the 'Protogine Zone', forming increasingly foliated granitoids (e. g. the Odalen granite) within the Southwest Scandinavian Domain, east of the Mylonite Zone (inset map, Fig. 1). In Norway a westward extension of TIB rocks into areas overprinted by Sveconorwegian events has been suggested by Oftedahl (1981) and it is well established in central southern Sweden (Larson & Berglund 1992; Wahlgren et al. 1994).

Foliated, older granitoids (11 in legend of Fig. 1), which were intruded by massive, younger granites in the Trysil area, are most likely of the same category as the older Värmland granites, e.g. the Filipstad granite which has a zircon age of 1783 ± 10 Ma (Jarl & Johansson 1988) and corresponds to the TIB 1 episode of Larson & Berglund (1992). Formation of the foliation, observed in the western parts of the Trysil volcanic rocks and the older granitoids, predates the intrusion of the 'Tricolor' granite (Heim 1989). The 1673 Ma intrusion age presented here allows a correlation of this ductile deformation with the D2 event of the Gothian orogeny, which occurred prior to (ca.) 1.66 Ga (Larson et al. 1990). The non-penetrative deformation, affecting the Jotnian cover (see above), may be the expression of the Sveconorwegian Frontal Deformation Zone (Wahlgren et al. 1994) in the area.

Conclusions

The petrography, geochemistry and isotope characteristics of the younger Trysil granitoids in general, and the 'Tricolor' granite in particular, lead to the following conclusions:

- The Trysil granitoids in the Norwegian part of the TIB are dominated by massive, I-type granites that intruded foliated granitoids of older Värmland type and Dala/Trysil volcanic rocks (TIB 1 and 2 of Larson & Berglund 1992).
- Of the younger granites, the common 'Tricolor' granite, with a U-Pb zircon crystallization age of 1673 ± 8 Ma, and a perthitic granite have similar geochemistry and isotope characteristics.
- Mineralogical differences among these granites may be due to different water content in the magma, the perthite-rich type reflecting crystallization from a dry magma, possibly at shallow crustal level.
- On the basis of petrography, geochemistry and age, the Trysil granitoids can be correlated with the Dala and Rätan granites, which in turn intruded during what is considered the post-volcanic TIB 3 episode of Larson & Berglund (1992).
- The isotope data indicate that the granitoids were derived from source rocks with a depleted mantle character and short crustal histories. The possible influence of older (Archaean) continental crust is negligible.
- Formation in a within-plate tectonic environment is suggested.
- Post-emplacement events (i.e. late Gothian or younger) are non-penetrative; the youngest deformation (probably Permian) involved brittle fault formation.
- Variably tectonized granitoids, equivalent in age to the younger Trysil granites, are likely to constitute major parts of the crust within the eastern part of the Southwest Scandinavian Domain.

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Appendix

Sample localities

Sample	Map	Zone	E-coor	N-coor	Description
TR-1	2018-2	32V	65715	684810	Road-cut on W-side of main road. Coarse-grained, biotite-bearing granite of 'Tricolor' type. Dykes of fine-grained dolerite and cm-thick shear veins with cataclastically granulated, quartz-epidote-rich fault rock.
TR-3A	2018-2	33V	34225	684075	Road-cut on E-side of main road. Medium-grained biotite-hornblende quartz diorite with dykes of TR-3B
TR-3B	2018-2	33V	34225	684075	Road-cut on E-side of main road. Feldspar-porphyritic, pink, aplitic biotite granite ('Tricolor' type) forming m-thick dykes in TR-3A
TR-4	2018-2	33V	34320	683215	Road-cut on E-side of main road. Massive, coarse-grained biotite granite ('Tricolor' type). Dated sample.
TR-8	2117-4	33V	35165	680045	Road-cut on W-side of timber road. Coarse-grained, greyish pink, amphibole-biotite bearing perthite granite.
TR-9	2117-4	33V	35130	680145	Road-cut on W-side of timber road. Very coarse-grained, greyish pink, biotite-bearing-perthite granite.
TR-10	2117-4	33V	35150	680140	Road-cut on W-side of timber road. Very coarse-grained, greyish pink, amphibole-biotite-bearing perthite granite.
TR-11A	2017-1	33V	35020	679840	Road-cut on north side of local road. Medium-grained, grey, biotite granite (dyke or border-facies of 'Tricolor' type).
TR-11B	2017-1	33V	34965	679815	Road-cut on north side of local road. Coarse-grained, greyish pink perthite granite.
TR-13	2117-4	33V	35170	680700	Road-cut. Medium-grained, slightly feldspar-porphyritic, hornblende-bearing biotite granodiorite.
TR-14	2018-2	33V	34685	682280	Block from minor quarry below timber road. Coarse-grained, biotite-bearing granite of 'Tricolor' type.