BARENTS PROJECT

U-Pb zircon age of a metagranite at Björnberget in the Pålkem area, northern Sweden

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Cover: Geologist Ulf Bergström in action during preparation of metagranite sample STB141943A at Björnberget. Photo: Stefan Bergman.

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ABSTRACT

A sample from a body of metagranite from the Pålkem area in northern Sweden has been dated with the U-Pb SIMS method on zircon. A concordia age has been calculated at 1885±5 Ma, which is interpreted to date igneous crystallisation. The result shows that the body belongs to an early Svecokarelian intrusive suite, and field relations suggest affinity to the Perthite monzonite suite rather than the coeval to slightly older Haparanda suite.

SAMMANFATTNING

Ett prov från en metagranitkropp i Pålkemområdet i norra Sverige har daterats med U-Pb-SIMS-metoden på zirkon. En konkordiaålder har beräknats till 1885±5 miljoner år. Vi tolkar att detta representerar tidpunkten för magmatisk kristallisation. Resultatet visar att kroppen tillhör en tidig svekokarelsk intrusionssvit, och fältrelationer indikerar att den snarare ingår i Pertit-monzonitsviten än den likåldriga till något äldre Haparandasviten.

Keywords: Radiometric age, U-Pb, zircon, metagranite, Perthite monzonite suite, Sveco-karelian orogen, Barents project.

INTRODUCTION

Felsic metaplutonic rocks with variable magnetic signatures dominate the bedrock in the Pålkem area (Bergström et al. 2015, Figs. 1–2). These rocks are assigned to four different intrusive suites: the Haparanda suite (1.89–1.88 Ga), the Perthite monzonite suite (1.88–1.86 Ga), the Lina suite (c. 1.8 Ga) and the Edefors suite (c. 1.8 Ga). The Haparanda suite is dominated by foliated, grey quartz monzodiorite to granodiorite with abundant mafic enclaves. These rocks are generally weakly deformed in the eastern part and more strongly deformed in the western part of the area. Weakly foliated to isotropic, reddish granite and quartz monzonite are most common in the Perthite monzonite suite. This suite dominates in the western and centralnorth-eastern parts of the study area. The Edefors suite, in the north-west and south-west, includes mainly coarse and porphyritic granite and quartz syenite, generally with no evident tectonic fabric. In Figure 3 the geochemical trends of three of these suites show a change from calc-alkaline to alkaline compositions with time. The Lina suite consists of isotropic to weakly foliated leucogranite, commonly associated with pegmatite.

The central north-eastern parts of the study area (dark brown in Fig. 1) is dominated by unevenly grained or porphyritic metagranite. The variably developed fabric of the metagranite led previous investigators to assign strongly deformed, weakly deformed and isotropic varieties to the Haparanda suite, the Perthite monzonite suite and the Edefors suite, respectively. Results from recent field investigations in the area suggest that the metagranite actually is a single, variably deformed unit (Bergström et al. 2015).

The magnetic anomaly map in Figure 2 shows north-north-west to north-east striking belts with banded patterns that mainly correspond to metavolcanic rocks. These are intruded by mainly felsic intrusive rocks in areas with more homogeneous magnetic patterns.

A conspicuous belt of relatively straight, thin magnetic anomalies occurs in the central part of Figure 2, also within the area of sample STB141043A. This belt is interpreted as a mafic dyke swarm that cross-cuts the folded metavolcanic belts as well as some areas of felsic intrusive rocks. Towards the north-west the dyke swarm is dragged into and cut off by a shear zone with apparent sinistral shear sense. East of sample STB141043A there is a low magnetic area where the dyke swarm is discontinuous. The presence of isotropic pegmatite granite in this area suggests that the dykes are cut by the pegmatite granite. The field relations at the sample site confirm these interpretations (see below).

The sampled outcrop at Björnberget is dominated by slightly foliated metagranite (Figs. 4A–C).

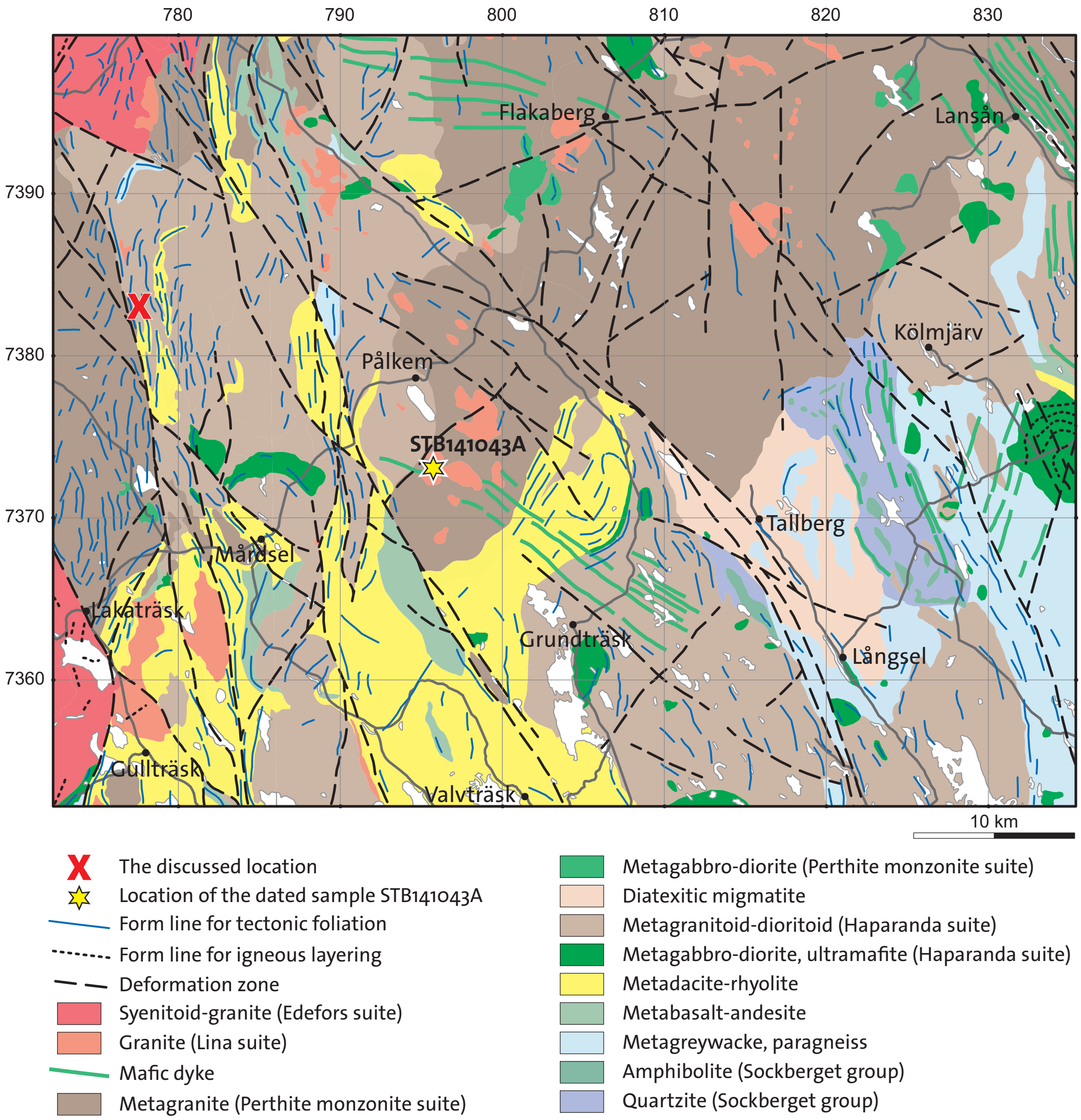

Figure 1. Bedrock map of the Pålkem area. Location of the dated sample STB141043A is shown by a yellow star. The red symbol "X" refers to a location discussed in the text.

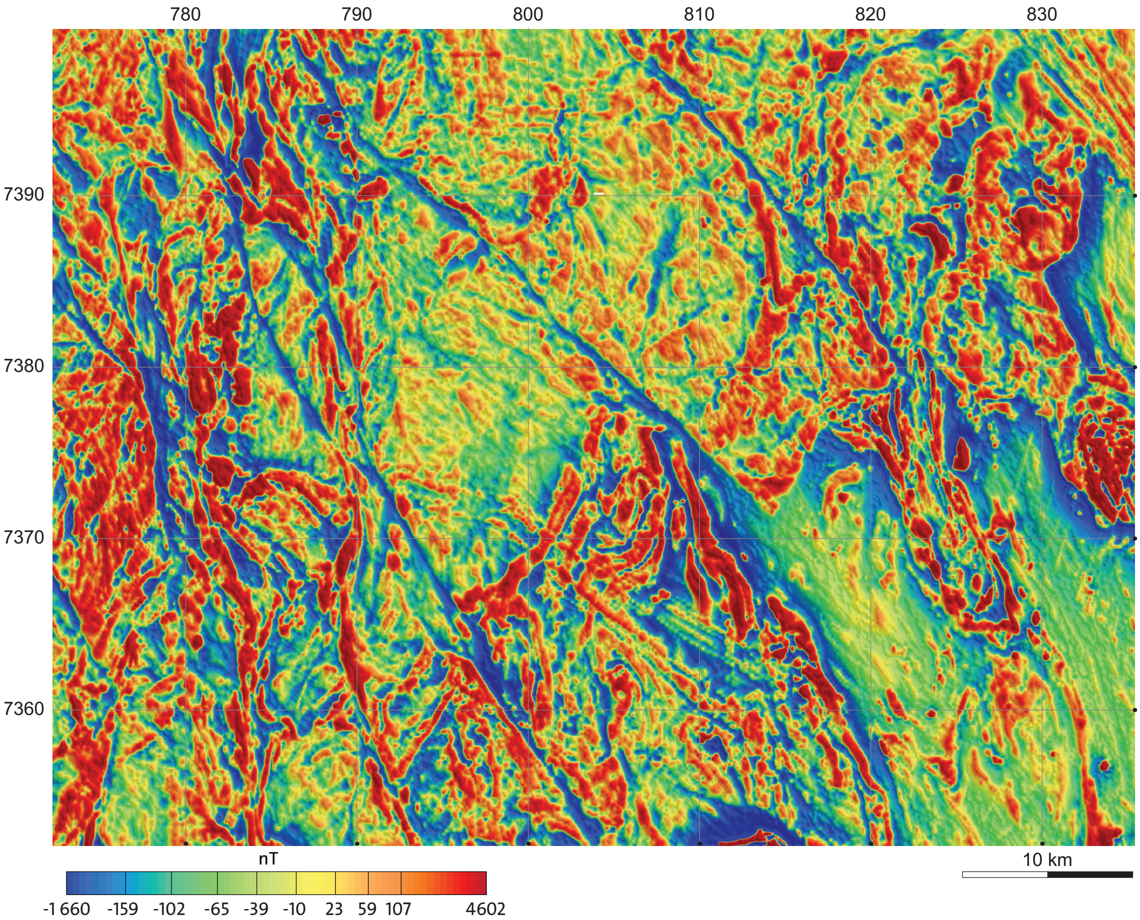

Figure 2. Magnetic anomaly map of the same area as in Figure 1. Note the banded and folded pattern of metavolcanic rocks striking north-east in the central part, and the north-west striking, cross-cutting, straight and thin magnetic bands of the mafic dyke swarm.

A few rounded mafic enclaves were observed. The metagranite is cut by a number of isotropic granitic dykes (Figs. 4A, D). Along the southern edge of the outcrop there are small exposures and local boulders of strongly magnetic, fine-grained amphibolite (Figs. 4A, E) with a pronounced hornblende lineation. In one place, a metre-wide dyke of pegmatitic granite cross-cuts the inferred metagranite–amphibolite contact at a high angle (Fig. 4A). This confirms the interpretation of the magnetic anomaly patterns, outlined above. The actual contacts of the amphibolite are not exposed.

The U-Pb zircon age of the metagranite STB141043A will give the age of the dominant lithology in the area as well as a maximum age of the mafic dyke swarm and the subsequent deformation, metamorphism and intrusion of pegmatite granite.

Sample description

Sample STB141043A (Table 1) is a slightly foliated, reddish grey, medium-grained, megacrystic metagranite (Fig. 4B). The main minerals are quartz, K-feldspar, plagioclase and brown biotite. Plagioclase is moderately sericitised and some biotite grains are altered to green chlorite and titanite. Accessory phases include bluish green hornblende, titanite, epidote, zircon and opaque minerals. The overall magmatic texture with megacrysts of K-feldspar and plagioclase in a medium-grained matrix is preserved, but in some domains a tectonic foliation is defined by elongate aggregates mainly of recrystallised quartz (Fig. 4C).

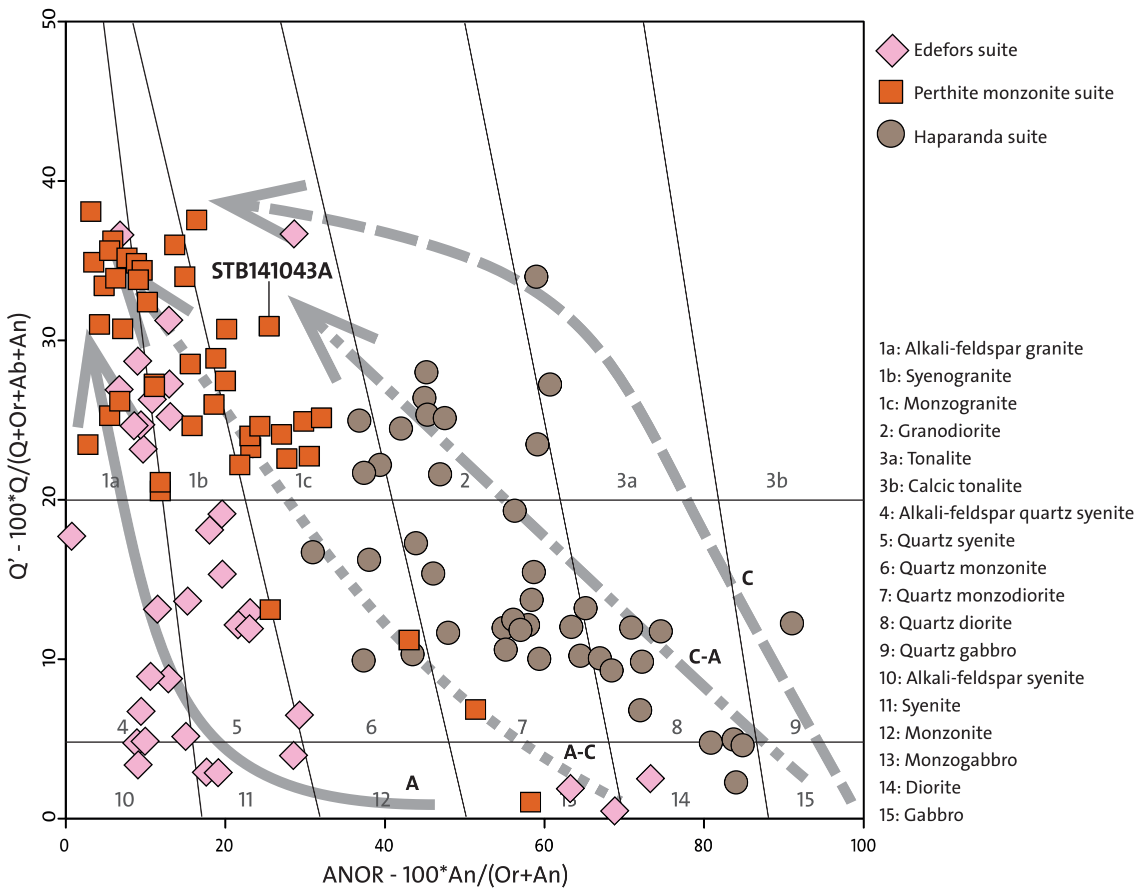

Figure 3. Geochemical data from intrusive rocks of the Perthite monzonite suite and the Haparanda suite in the south-eastern part of Norrbotten county, plotted in the CIPW normative Q-ANOR diagram (Streckeisen & LeMaitre 1979). The suite trends shown by grey arrows (C = calcic, C-A = calc-alkalic, A-C = alkali-calcic and A = alkalic) are from Whalen & Frost (2013).

Table 1. Summary of age sample data.

Rock type	Porphyritic metagranite
Lithotectonic unit	Norrbotten lithotectonic unit in the Svecokarelian orogen
Lithologic unit	Perthite monzonite suite
Sample number	STB141043A
Lab-id:	n5173
Coordinates	7372883/795964 (Sweref99TM)
Map sheet	73H 7j (Sweref99TM), 26L Pålkem (RT90)
Locality	Björnberget
Project	Kartering Barents (27007)

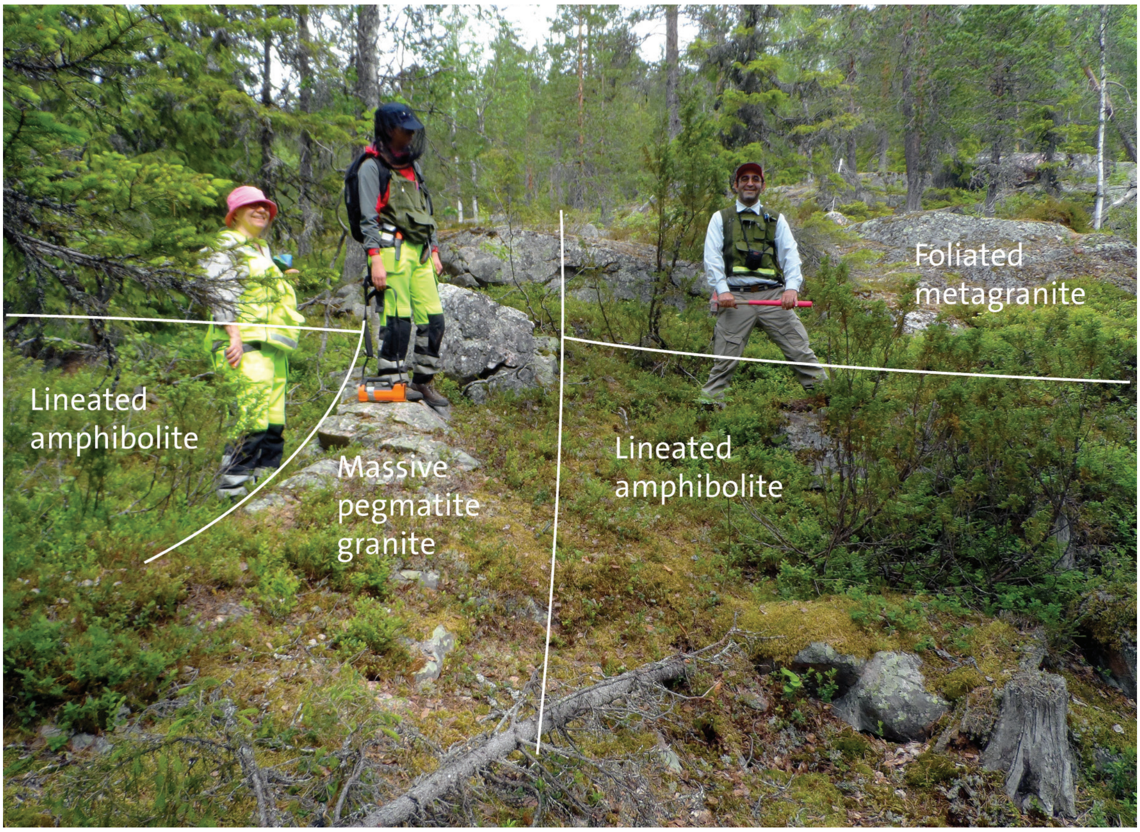

Figure 4 A. Field relations near the sampling locality where the contact between foliated metagranite and lineated amphibolite is cut at a high angle by a massive pegmatite granite dyke. The persons are, from left to right, Lena Persson, Joanna Holmgren and Martiya Sadeghi.

Analytical results and interpretation of geochronological data

Zircons were obtained from a density separate of a crushed rock sample using a Wilfley water table. The magnetic minerals were removed by a hand magnet. Handpicked crystals were mounted in transparent epoxy resin together with chips of reference zircon 91500. The zircon mounts were polished and after gold coating examined by back scatted electron (BSE) and cathodoluminescence (CL) imaging using electron microscopy at EBC, Uppsala University, and at the Swedish Museum of Natural History in Stockholm. High-spatial resolution secondary ion mass spectrometer (SIMS) analysis was done in November and December 2014 using a Cameca IMS 1280 at the Nordsim facility at the Swedish Museum of Natural History in Stockholm. Detailed descriptions of the analytical procedures are given in Whitehouse et al. (1997, 1999) and Whitehouse & Kamber (2005). A c. 6 nA O^{2-} primary ion beam was used, yielding spot sizes of c. 15 µm. Pb/U ratios, elemental concentrations and Th/U ratios were alibrated relative to the Geostandards zircon 91500 reference, which has an age of c. 1 065 Ma (Wiedenbeck et al. 1995, 2004). Common Pb corrected isotope values were calculated using modern common Pb composition (Stacey & Kramers 1975) and measured ^{204}Pb, in cases of a ^{204}Pb count rate above the detection limit. Decay constants follow the recommendations of Steiger & Jäger (1977). Diagrams and age calculations of isotopic data were made using the software Isoplot 4.15 (Ludwig 2012). All age uncertainties are presented at the 2σ level. BSE-imaging of the dated zircons was performed using electron microscopy at the Department of Geology, Uppsala University.

Figur 4 B. K-feldspar megacrystic metagranite with mafic enclave, near the sample locality of STB141043A.

Figur 4 C. Photomicrograph of the dated sample. Domains of elongate aggregates of recrystallised quartz and minor feldspar define a tectonic foliation between less deformed domains with megacrysts of K-feldspar and plagioclase. Crossed nicols. The long dimension of the photograph is c. 12 mm.

Figur 4 D. Contact between K-feldspar megacrystic metagranite and pegmatite dyke. E. Lineated amphibolite from a dyke that cross-cuts the sampled metagranite.

All photographs by Stefan Bergman.

The heavy mineral concentrate is rich in zircon. Most are turbid, but there are also clear, transparent colourless grains, which were selected for analysis. The zircon has subhedral to euhedral prismatic shapes. BSE images show oscillatory zoned zircon (Fig. 5). In some grains there seems to be texturally older cores in the central parts of the grains.

The analyses contain 168–355 ppm U and have variable Th/U ratios of 0.15–0.80 (Table 2). Two of the analyses (5a and 8a) are strongly discordant, and one of these also has high values of common lead (Table 2). The remaining analyses are concordant at the 2σ level and with a concordia age of 1885±5 Ma (2σ, n = 7, MSWD (of concord. & equiv.) = 0.59, probability (of concord. & equiv.) = 0.87, Fig. 6), identical with the weighted average $^{207}Pb/^{206}Pb$ age of 1 885±5 Ma (2σ, MSWD = 0.37, probability = 0.90, n = 7). The 1 885±5 Ma age is interpreted to date igneous crystallisation of the metagranite.

Table 2. SIMS U-Pb-Th zircon data (STB141043A, laboratory id n5173).

Sample/ spot #	n5173_01a	n5173_02a	n5173_03a	n5173_04a	n5173_05a	n5173_06a	n5173_07a	n5173_08a	n5173_09a
U, ppm	240	274	200	168	312	243	200	355	293
Th, ppm	97	115	68	130	84	90	108	114	131
Pb, ppm	101	117	82	77	53	100	86	92	124
Th/U, calc *1	0.42	0.45	0.35	0.80	0.15	0.39	0.55	0.23	0.46
$^{207}Pb/^{235}U$	5.397	5.460	5.383	5.439	2.234	5.333	5.345	3.391	5.413
±σ, %	1.07	1.01	1.07	1.07	3.02	1.07	1.13	1.22	0.99
$^{208}Pb/^{232}Th$	0.1006	0.1036	0.1008	0.1009	0.0526	0.1039	0.1008	0.0688	0.1006
±σ, %	2.07	2.05	2.12	2.06	6.14	2.14	2.46	2.18	2.03
$^{238}U/^{206}Pb$	2.945	2.901	2.954	2.926	7.100	2.984	2.973	4.676	2.945
±σ, %	0.98	0.96	1.01	1.00	2.59	1.02	1.07	1.17	0.94
$^{207}Pb/^{206}Pb$	0.1153	0.1149	0.1153	0.1154	0.1151	0.1154	0.1153	0.1150	0.1156
±σ, %	0.43	0.33	0.37	0.39	1.57	0.33	0.37	0.35	0.30
r *2	0.91	0.95	0.94	0.93	0.85	0.95	0.95	0.96	0.95
Disc. %, conv. *3	0.0	1.9	-0.4	0.6	-58.4	-1.4	-0.9	-36.8	-0.3
Disc. %, 2σ lim. *4					-50.5			-34.7	
$^{207}Pb/^{206}Pb$	1884	1878	1885	1886	1881	1886	1884	1880	1889
±σ	8	6	7	7	28	6	7	6	5
$^{206}Pb/^{238}U$	1885	1909	1879	1895	849	1863	1869	1249	1884
±σ	16	16	16	16	21	17	17	13	15
$^{206}Pb/^{204}Pb$	>1e6	419906	297387	>1e6	689	126581	880260	21163	407378
f_{206}% *5	{0.00}	{0.00}	{0.01}	{0.00}	2.72	{0.01}	{0.00}	0.09	{0.00}

Isotope values are common Pb corrected using modern common Pb composition (Stacey & Kramers 1975) and measured ^{204}Pb.
*1 Th/U ratios calculated from $^{208}Pb/^{206}Pb$ and $^{207}Pb/^{206}Pb$ ratios, assuming a single stage of closed U-Th-Pb evolution
*2 Error correlation in conventional concordia space. Do not use for Tera-Wasserburg plots.
*3 Age discordance in conventional concordia space. Positive numbers are reverse discordant.
*4 Age discordance at closest approach of error ellipse to concordia (2σ level).
*5 Figures in parentheses are given when no correction has been applied, and indicate a value calculated assuming present-day Stacey-Kramers common Pb.

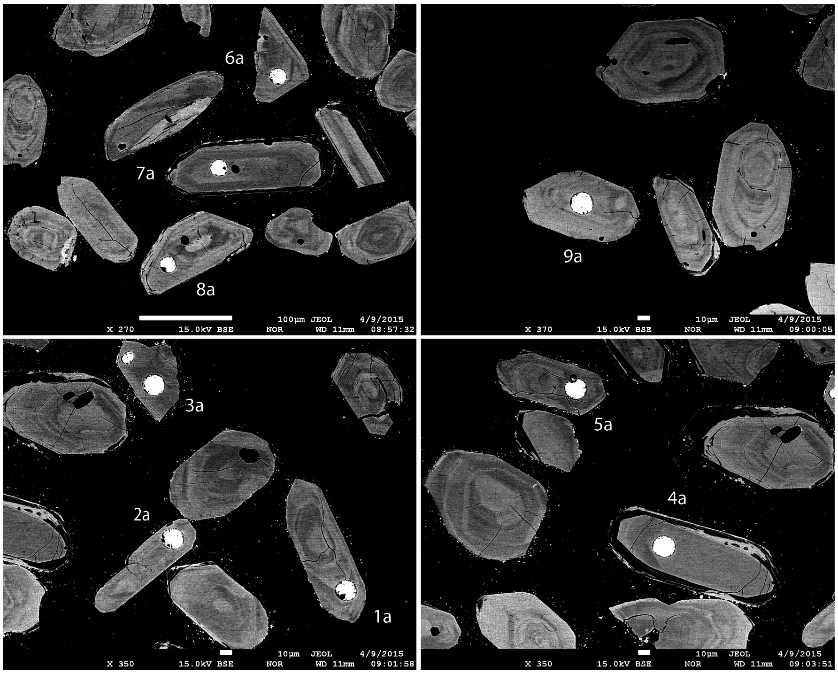

Figure 5. Back-scattered electron (BSE) images of analysed zircon grains. White spots mark the locations of analyses. Numbers refer to analytical spot number in Table 2.

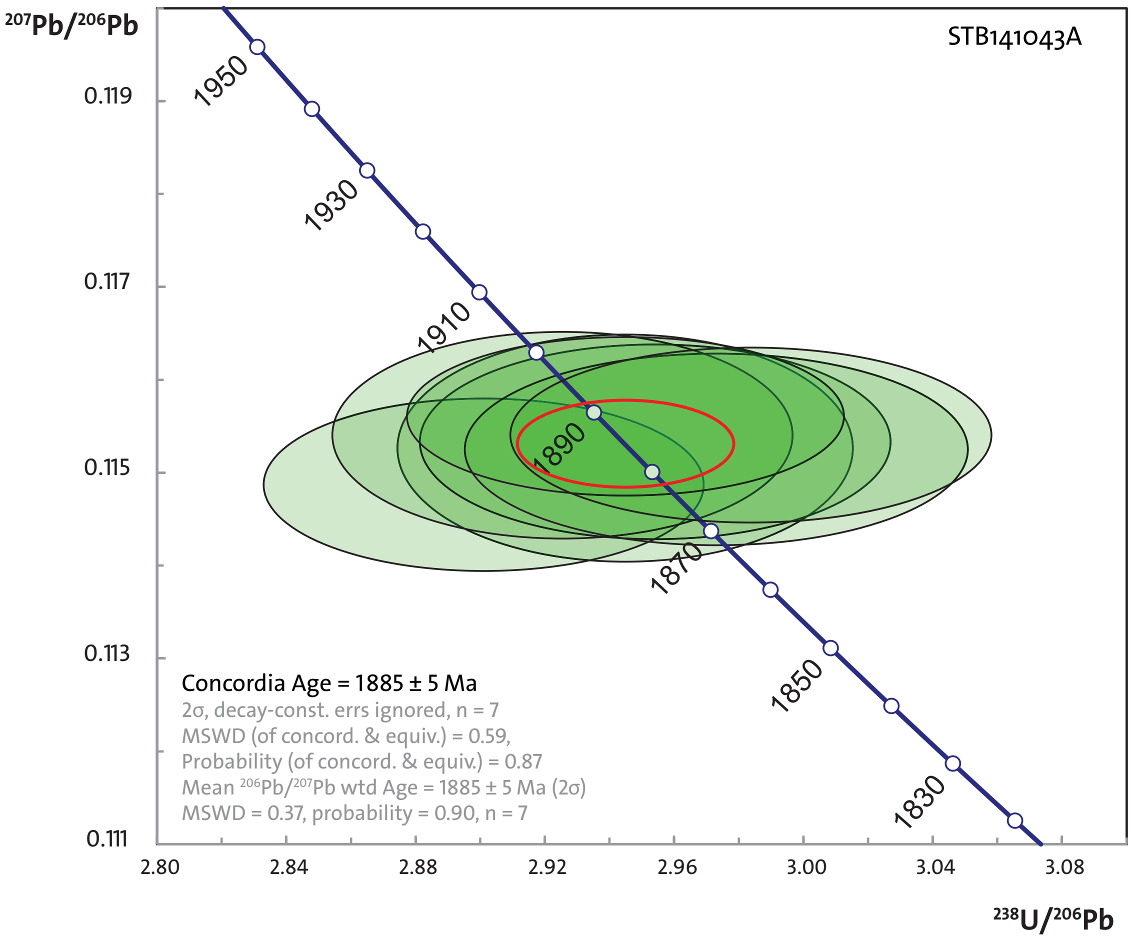

Figure 6. Tera Wasserburg diagram showing U-Pb SIMS data of zircon analyses. Two strongly discordant analyses (5a and 8a) are excluded from the diagram and the age calculation, see Table 2. Error ellipse of calculated weighted mean age is shown in red.

DISCUSSION AND CONCLUSION

The crystallization age 1885±5 Ma shows that the metagranite belongs to an early Svecokarelian intrusive suite rather than the late Svecokarelian c. 1.8 Ga old Edefors suite. It also gives a maximum age of the cross-cutting mafic dykes as well as the overprinting, weak tectonic foliation.

In the western part of Figure 1 there is a granite pluton that is petrographically identical to the dated body at Björnberget. In the contact zone between that pluton and a metaquartz monzodiorite belonging to the Haparanda suite (marked with "X" in Fig. 1) weakly foliated, red granite dykes cross-cut a strong penetrative fabric in metaquartz monzodiorite. Such field relationships have previously been reported from a few localities in northernmost Sweden (Bergman et al. 2001) and the Skellefte district (e.g. Lundström et al. 1999). They have been taken as evidence for a deformation event between the formation of the Haparanda and Perthite monzonite suites at c. 1.88 Ga. The cross-cutting relationship between the mafic dyke swarm and the folded c. 1.89 Ga old metavolcanic rocks in the Pålkem-Valvträsk area (Figs. 1–2) suggests that the main folding of the metavolcanic rocks also occurred at this time (Bergström et al. 2015).

Previous age determinations in northern Sweden have given 1.89–1.88 Ga for the Haparanda suite and 1.88–1.86 Ga for the Perthite monzonite suite. The present result, which is one of the oldest, does not distinguish between these suites. Recent dating results from weakly deformed metagranite and granitic augen gneiss in the south-western part of Norrbotten county (Hellström et al. 2015) confirm the age interval of the Perthite monzonite suite. Geochemical data show that the Haparanda suite has a calc-alkalic to alkali-calcic trend, whereas the Perthite monzonite suite is alkali-calcic (Fig. 3), which is in agreement with previous results from northern Sweden (Skiöld et al. 1988, Skiöld & Öhlander 1989, Ahl et al. 2001, Bergman et al. 2001). The dated sample plots within the trend of the Perthite monzonite suite, but close to the calc-alkalic trend that is characteristic of the Haparanda suite (Fig. 3).

Although a significant difference in age within error between the Haparanda and Perthite monzonite suites cannot be shown by presently available methods, they appear to have different deformation histories. A change in magmatism during a deformation event that rapidly decreased in intensity was proposed by Bergman et al. (2001). In a tectonic model for south-eastern Sweden, Stephens & Andersson (2015) suggested a scenario with an active continental margin with a progressive oceanward migration of the subduction system, where longer periods of extension or transtension due to retreat of the subduction boundary were intervened by shorter events of transpression due to advance of that boundary. Applying this model to northern Sweden suggests that the Perthite monzonite suite formed when the subduction boundary changed from an advancing to a retreating mode.

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