U-Pb zircon age of an Archean granodioritic gneiss in the Boden area, northern Sweden

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Cover: A view from sampling locality at Unbyn
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CONTENT

ABSTRACT

Rocks of a proposed Archean age have been recognized in the Boden area in northern Sweden during bedrock mapping of the geological survey of Sweden. One of these, a granodiorite gneiss from Unbyn, south of Boden, has been dated with U-Pb SIMS method on zircon. The calculated concordia age of 2.66 Ga is interpreted as the estimated igneous crystallization age.

Keywords*: Archean, Norrbotten, Boden, Unbyn, radiometric age, U-Pb, Svecokarelian orogen*

SAMMANFATNNING

Bergarter med föreslagen arkeisk ålder har hittats i Bodenområdet i norra Sverige under berggrundskartering av Sveriges geologiska undersökning. En av dessa, en granodioritisk gnejs från Unbyn, söder om Boden, har daterats med U-Pb SIMS-metoden på zirkon. Den beräknade konkordiaåldern på 2,66 miljarder år tolkas som den magmatiska kristallisationsåldern.

Nyckelord: *Arkeikum, Norrbotten, Boden, Unbyn, radiometrisk ålder, U-Pb, svekokarelska bergskedjebildningen*

INTRODUCTION

Archean granitoid complexes in the Baltic shield have divided to four main ages (e.g. Slabunov et al. 2006): Paleoarchean granitoids older than 3.2 Ga; granitoids formed 3.2–2.8 Ga ago; and granitoids formed 2.75–2.50 Ga ago including TTG rocks, diorite, and enderbites and subalkaline and alkaline rocks, syenite, alkali granite and nepheline syenite.

Rocks of Archean age in Sweden are mainly exposed in the Råstojaure complex in northernmost part of the country, but small, scattered remnants of Archean rocks have also been found elsewhere in the Norrbotten County (Martinsson et al. 1999, Mellqvist 1999, Mellqvist et al. 1999 and reference therein). A transition zone, in a WNW direction, extending from the Luleå area, on the coast of the Gulf of Bothnia, towards Jokkmokk, separates the Archean craton in the northeast from a Paleoproterozoic more juvenile area in the southwest (Öhlander et al. 1993, 1999; Mellqvist 1999; Mellqvist et al. 1999). Sm-Nd isotopic analyses approximately delineate the Archean paleoboundary zone, where negative $\varepsilon Nd_{(1.9\,Ga)}$ values of Proterozoic granitoids and metavolcanic rock trace Archean source rocks underneath, which by c. 1.9 Ga had acquired distinctly negative εNd values. To obtain a more precise delineation of the southern border of the concealed Archean craton in addition to previous work, samples from different places in the Boden area have been taken. From those samples, one sample with strongly negative $\varepsilon Nd_{(1.9\,Ga)}$ value from the Unbyn area was selected for U-Pb zircon dating (Fig. 1)

The Archean rocks in the Boden area is found in Unbyn and to the north and northeast (Fig. 1) where Archean rock previously has been reported (e.g. Mellqvist 1999 and reference therein). The dominating type of Archean rocks is a porphyritic metagranitoid. According to the Q-P diagram (after Debon & LeFort 1982) the composition ranges from granodiorite to monzodiorite. At several places in this area, Archean rocks are intruded by gabbroic rocks and younger, 1.8 Ga granite. The Archean rocks are variably deformed and exhibit gneissic structures, recrystallisation and alteration. The Archean rocks show more deformation and higher degree of metamorphism than the surrounding Haparanda and Edefors suite rocks (Mellqvist 1999; Kathol et al. 2011, 2012).

SAMPLE DESCRIPTION

The sample was taken from well exposed outcrop from Lillberget close to the main road (Fig. 1, Table 1). The locality shows a TTG-gneiss and a porphyritic granitoid in contact with a younger 1.8 Ga granite. The rocks are deformed with a strongly pronounced foliation and lineation and the younger granite crosscut structure relationship. The εNd value from this sample is -12.0 at t = 1.89 Ga (SGU unpublished data) and this value is close to the εNd value achieved by Mellqvist (1999) from a sample of a porphyritic metagranitoid a few kilometers north of this sample location. The sample is classified as granite to granodiorite based on modal analysis and granodiorite according to the Q-P geochemical classification diagram (after Debon & LeFort 1982). The sample shows a distinct gneissic structure and porphyritic texture with microcline up to 4 cm. Mafic minerals are dominated by olive-green biotite.

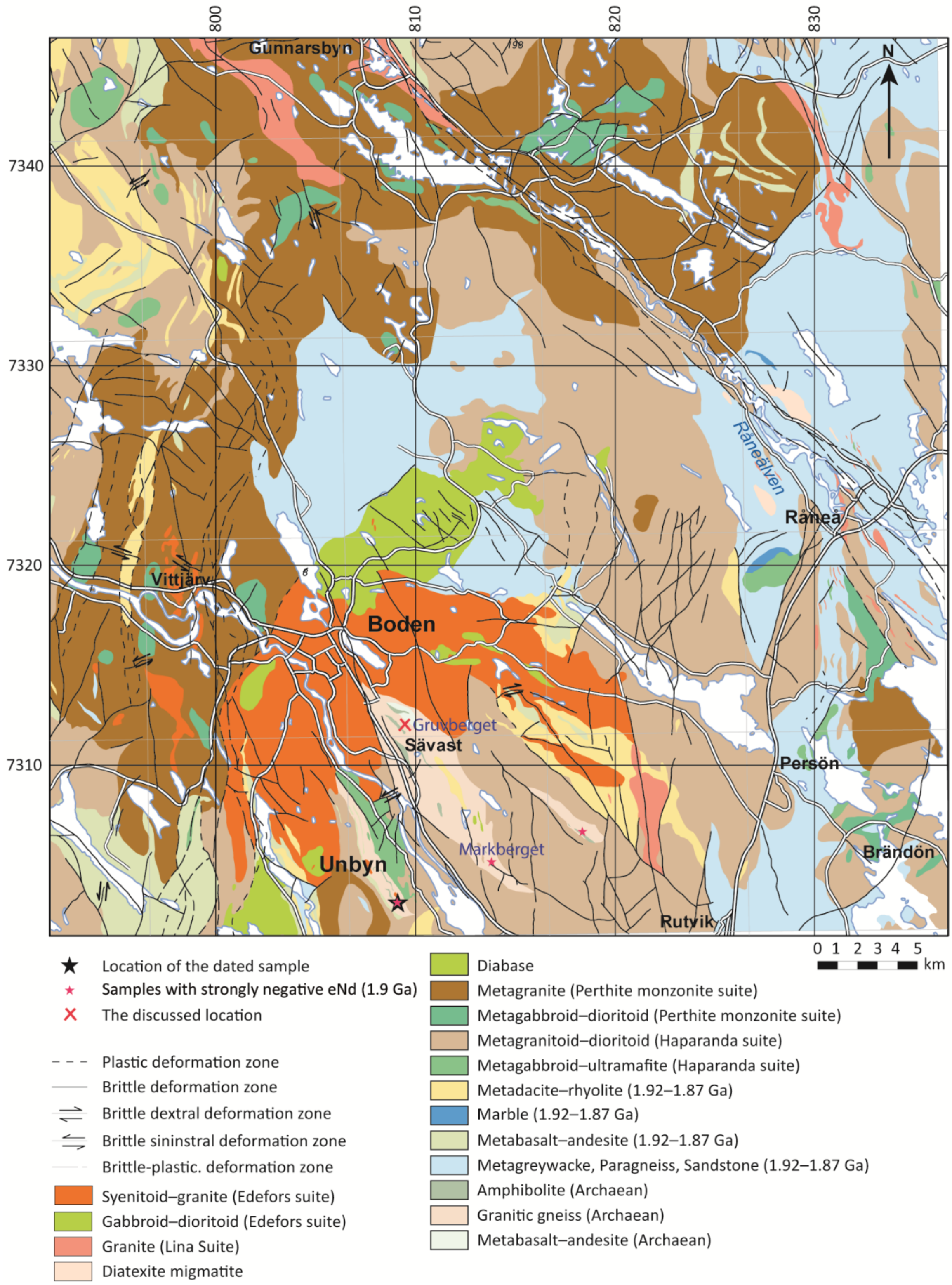

Figure 1. Generalised bedrock map of the Boden area. Location of the dated sample (RKN100114K) is shown by a black star.

Table 1: Summary of sample data (RKN100114K).

Rock type	Porphyritic granodioritic gneiss
Tectonic domain	Svecokarelian orogen
Tectonic subdomain	Norrbotten lithotectonic unit
Stratigraphic group	Archean rocks
Sample number	RKN100114K
Lab-id (Nordsim)	n4058
Coordinates	7303260 / 809224 (Sweref 99TM)
Map sheet	73i, 0a SO (Sweref 99TM) 25L Boden (RT90)
Locality	Lillberget -Unbyn
Project	Jäkkvik-Boden

Figure 2. Typical Archean porphyritic granitoid at the Unbyn dating location.

Figure 3. Close-up view of the dated rock in contact with younger, light red leucogranite (RKN10011403, see Figure 2). Photo: Risto Kumpulainen.

ANALYTICAL RESULTS AND INTERPRETATION OF GEOCHRONOLOGICAL DATA

U-Pb-Th SIMS analysis of zircon was performed at the NORDSIM facility at the Museum of Natural History in November 2011. The analytical results are shown in Table 2. 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 scattered electron (BSE) 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 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. U/Pb ratios, elemental concentrations and Th/U ratios were calibrated relative to the Geostandards zircon 91500 reference, which has an age of c. 1065 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 software Isoplot 4.15 (Ludwig 2012). All age uncertainties are presented at the 2σ or 95% confidence level. BSE-imaging of the dated zircons was performed using electron microscopy at the Department of Geology, Uppsala University.

The heavy mineral concentrate from 496 g of processed sample contains abundant zircon grains with subhedral to anhedral, somewhat rounded shapes. Most zircons are turbid and rich in cracks, but there are also a few clear crystals of good analytical quality, which were selected for analysis.

BSE images show weakly oscillatory zoned crystals or a BSE-homogenous colour (Fig. 4). Some crystals have a central BSE-bright domain, resembling cores. An analysis of such domain (2c) shows a high U content, 1353 ppm and low Th/U ratio, 0.21 (Table 2). The zircon U content of the other analyses is rather uniform 146−386 ppm, and Th/U ratios are 0.38−2.0. All analyses are concordant but spread somewhat along the concordia and it is not possible to calculate a concordia age (Fig. 5). Three of the analyses (11, 10, 7) are somewhat younger with ^{207}Pb/^{206}Pb ages 2.64−2.63 Ga, excluding also (5, 2c) with ^{207}Pb/^{206}Pb ages at 2.65 Ga, it is possible to calculate a concordia age at 2661 ±3 Ma (n = 11; MSWD of concordance and equivalence = 1.9; probability of concordance = 0.22). The weighted average ^{207}Pb/^{206}Pb age for the same analyses are 2661 ± 4 Ma (MSWD = 2.8, probability = 0.002). Including also the analyses (5, 2c), the weighted average ^{207}Pb/^{206}Pb age is 2658 ±5 Ma (MSWD = 4.4, probability = 0.000).

The concordia age of the eleven oldest analyses is chosen as the best age estimate suggesting igneous crystallisation of the porphyritic metagranodiorite at c. 2.66 Ga. The reasons for the lower ages of grains 7, 10, 11 at 2.64−2.63 Ga are uncertain, no obvious differences are revealed from BSE-images compared to other grains analysed, but possibly these are affected by secondary alterations as the granodiorite has a gneissic structure. The quoted age of 2661 ±3 Ma therefore need to be taken with some caution.

Figure 4. BSE-images of zircon grains with location of spot analyses. Numbers refer to analytical spot number in Table 2.

Table 2. SIMS U–Pb–Th zircon data (RKN100114, n4058).

Nr	U ppm	Th ppm	Pb ppm	Th/U calc[1]	^{238}U/ ^{206}Pb	±s %	^{207}Pb/ ^{206}Pb	±s %	Disc. % conv.[2]	Calculated ages (Ma) ^{207}Pb/ ^{206}Pb	±s	^{206}Pb/ ^{238}U	±s	^{206}Pb/ ^{204}Pb	f_{206}%[3]
02c	1353	282	845	0.21	1.982	1.25	0.1798	0.12	-0.8	2651	2	2633	27	318103	0.01
02r	253	201	181	0.81	1.967	1.34	0.1804	0.21	-0.3	2656	3	2650	29	>1e6	{0.00}
3	386	400	286	1.04	1.983	1.38	0.1798	0.25	-0.8	2651	4	2633	30	410516	{0.00}
4	146	282	130	2.00	1.933	1.44	0.1807	0.28	1.3	2659	5	2687	32	536593	{0.00}
5	197	260	157	1.36	1.943	1.38	0.1793	0.24	1.4	2647	4	2676	30	204774	{0.01}
6	356	527	287	1.48	1.979	1.59	0.1813	0.18	-1.3	2665	3	2636	35	372403	{0.01}
7	224	202	162	0.92	1.988	1.38	0.1775	0.38	-0.2	2630	6	2626	30	167406	{0.01}
8	202	199	150	1.00	1.968	1.41	0.1818	0.34	-1.0	2670	6	2649	31	636432	{0.00}
9	288	436	236	1.54	1.959	1.31	0.1806	0.26	0.0	2658	4	2658	29	>1e6	{0.00}
10c	227	187	161	0.83	1.983	1.24	0.1780	0.26	-0.1	2635	4	2632	27	187742	{0.01}
11c	311	130	206	0.43	1.963	1.32	0.1786	0.20	0.7	2640	3	2654	29	310712	{0.01}
12c	219	282	178	1.35	1.908	1.19	0.1813	0.22	2.4	2665	4	2717	26	109087	0.02
13c1	213	331	176	1.62	1.964	1.25	0.1802	0.22	-0.1	2654	4	2653	27	212567	{0.01}
14c	360	133	237	0.38	1.953	1.31	0.1815	0.17	-0.1	2667	3	2666	29	380975	{0.00}
15r	193	289	161	1.56	1.927	1.29	0.1800	0.23	1.9	2653	4	2695	29	135295	0.01
16c	327	225	234	0.72	1.919	1.14	0.1816	0.31	1.6	2668	5	2703	25	26296	0.07

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 corrected for Pb_{com}, assuming a single stage of closed U-Th-Pb evolution.
2 Age discordance in conventional concordia space. Positive numbers are reverse discordant.
3 % of common ^{206}Pb in measured ^{206}Pb, estimated from ^{204}Pb assuming a present-day Stacey and Kramers (1975) model.
Figures in parentheses are given when no correction has been applied.

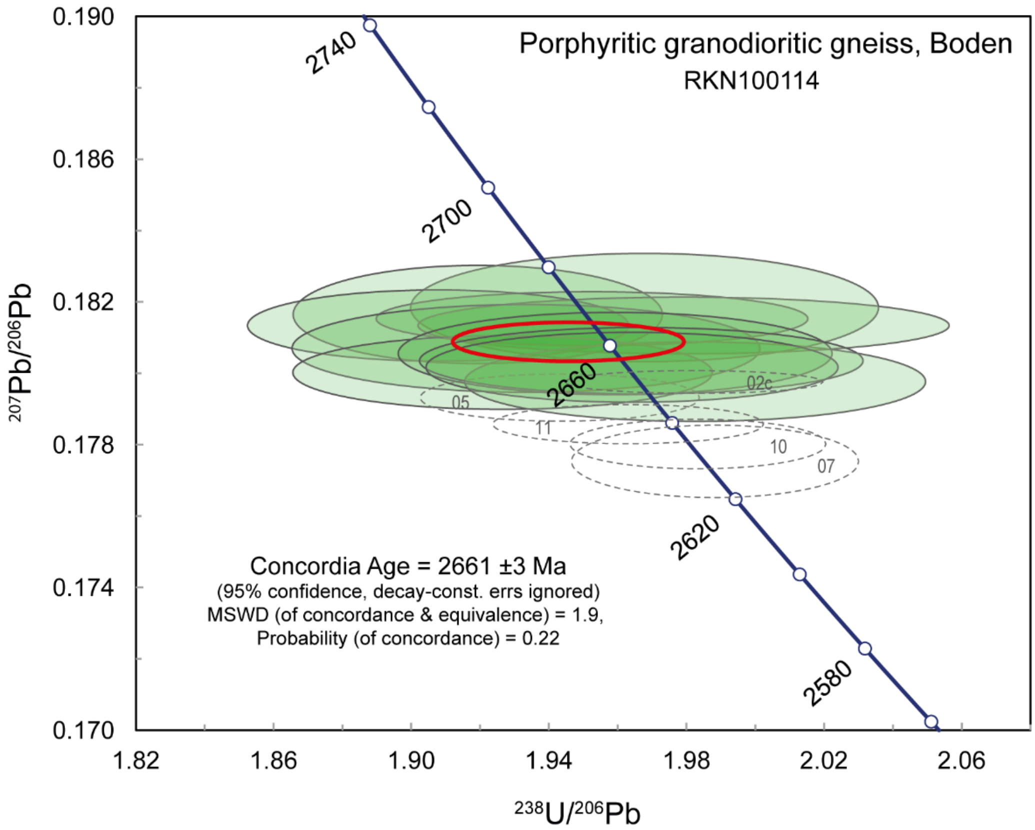

Figure 5. Tera Wasserburg diagram showing U-Pb SIMS zircon data. Analyses used for age calculation are shown in green. Analyses with dotted outlines are excluded, see text. Error ellipse of calculated weighted mean age is shown in red.

DISCUSSION AND CONCLUSION

In this study, zircons from a gneissic granodiorite at Unbyn, south of Boden have been dated at 2661 ±3 Ma, which is interpreted to represent the igneous crystallisation age of the granodiorite. Age determinations of Archean rocks have previously been reported from the nearby Luleå area (e.g. Vallen-Alhamn, Bälingsberget, Måttsundsberget) by several researchers (e.g. Lundqvist et al. 1996, Wikström et al. 1996, Mellqvist et al. 1999 and references therein). The obtained age at c. 2.66 Ga in this study is similar to the results from these studies (c. 2.71–2.65 Ga). The Archean rocks vary from meter-scale to tectonic blocks on a kilometre-scale size, relatively undisturbed by younger magmatism. Variably deformed gneissic granodiorite like the rocks in the Unbyn area was also found on the northern side of Gruvberget during the mapping program and field observation. Both structural and intrusive contact with the younger rocks within this area has been observed and documented (Sadeghi et al. *in press*). The Sm/Nd isotope analysis of the granitoid rocks from Gruvberget and Markberget shows strong negative εNd values similar to the Unbyn area (Fig. 1). At Gruvberget, volcaniclastic conglomerate, greywackes, and amphibolites occur. Intrusion of the Archean granodiorite likely caused the metamorphism and possibly limited melting of the supracrustal rocks. There is also a significant amount of possibly syn-magmatic gabbro that occurs spatially close to the granodiorite, most notable southeast of Gruvberget and on Markberget. Areas with exposed Archean rocks often coincide with magnetic lows on the aeromagnetic map.

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