BARENTS PROJECT

U-Pb zircon age of a Lina suite granite at the Archean–Proterozoic palaeoboundary south of Jokkmokk, northern Sweden

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Cover: Lina granite exposed in the Luleå river bed north of Jokkmokk. Photo: George Morris.

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ABSTRACT
The Archean–Proterozoic palaeoboundary in northern Sweden is approximately outlined by Sm-Nd isotopic data from c. 1.8 Ga intrusive rocks and define the boundary between the Norrbotten and Bothnia–Skellefteå lithotectonic domains. An isotropic leucogranite was sampled at Slättkullen south of Jokkmokk, immediately north of and on the Archean side of the proposed boundary zone. The concordia age of 1790±5 Ma (2σ) confirms that this granite belongs to the late Svecokarelian Lina suite and helps define the age of the suite in this area. One older inherited zircon core was identified with a concordant age of c. 1.88 Ga, a ubiquitous age for Proterozoic crust in this part of Norrbotten. While this result does not preclude the presence of Archean crust at depth in this area, it does suggest that the source of the Lina granite here is, at least in part, the Proterozoic bedrock.

Keywords: Granite, Lina suite, Proterozoic, Archean, palaeoboundary, U-Pb zircon date, Barents project

SAMMANFATTNING
Den arkeisk–proterozoiska paleogränsen i norra Sverige, vars ungefärliga läge är bestämt av Sm-Nd-isotopdata från ca 1,8 miljarder år gamla intrusiva bergarter, definierar gränsen mellan Norrbottens och Botnia-Skellefteå litotektoniska domäner. En massformig leukogranit provtogs vid Slättkullen söder om Jokkmokk, omedelbart norr om och på den arkeiska sidan av den föreslagna gränszonen. Konkordiaåldern 1790±5 Ma (2σ) bekräftar att denna granit tillhör den sensvekokarelska Linasviten och bidrar till att begränsa åldersintervallet av sviten i detta område. En äldre, ärvd zirkonkärna identifierades med en konkordant ålder av ca 1,88 miljarder år, en vanlig ålder för den proterozoiska berggrunden i Norrbotten. Även om detta resultat inte utesluter förekomsten av arkeisk berggrund på djupet inom detta område, antyder det att Linagranit här har, åtminstone delvis, proterozoiskt ursprungsmaterial.

Nyckelord: Granit, Linasviten, proterozoikum, arkeikum, paleogräns, U-Pb-zirkondatering, Barentsprojektet

INTRODUCTION

Granites of the Lina suite outcropping to the south of Jokkmokk provide two points of interest. The granite is largely undeformed and therefore provides a latest date for the end of deformation in the area. Granitic magmas also provide geochemical and mineralogical probes of the source rock as well as any older crust encountered between the source and emplacement levels. Xenoliths are commonly observed in the Lina granite and this sample indeed shows a more mafic zone that is interpreted to be a disaggregated xenolith. The Lina suite is generally thought to be rich in xenocrystic material, including inherited zircons.

The sample site is situated close to the poorly defined boundary between the Norrbotten and Bothnia–Skellefteå lithotectonic domains (Mellqvist et al. 1999, M.B. Stephens, pers. comm. 2013), just to the north-east of the proposed boundary (Fig. 1, Table 1). While the Archean–Proterozoic palaeoboundary is reasonably well defined near the coast, its location and nature inland is much less clear. Mellqvist et al. (1999), based on changes in the ε_{Ndi} ratios, proposed that the contact is low angled with Archean basement extending a considerable distance southwards under and interleaved with the Proterozoic crust.

SAMPLE DESCRIPTION

The dated sample (Fig. 2) is a typical Lina granite with a medium grain size (3–5 mm) and containing approximately 5% K-feldspar phenocrysts measuring up to 10 mm in size. The overall mineral composition is approximately 60% K-feldspar, 30% quartz, 5% plagioclase and less

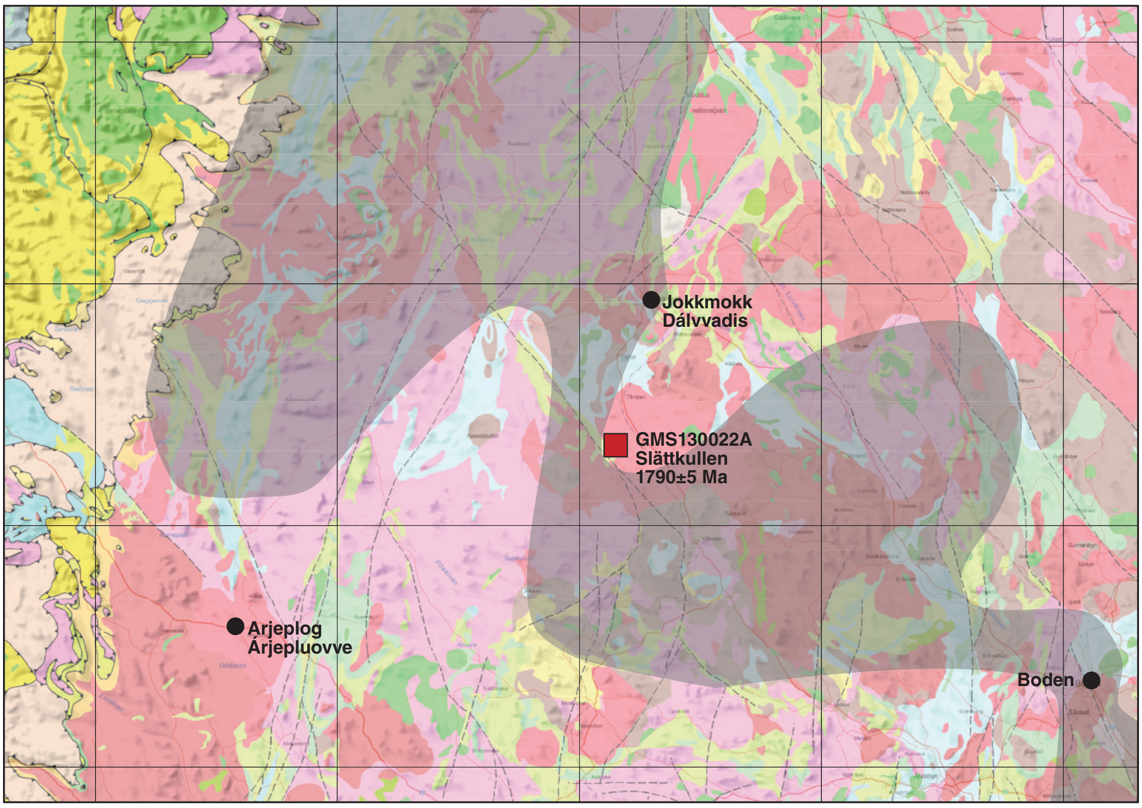


Figure 1. Location of the Lina suite granite sample dated for this report. The shaded zone lying south and west of the sample site GMS130022A is defined by intermediate ε_{Ndi} ratios and is tentatively taken to be the boundary between the Archean Norrbotten and the Proterozoic Bothnia–Skellefteå lithotectonic domains with Archean basement to the north-east and Proterozoic bedrock to the south-west (Mellqvist et al. 1999).

than 5% biotite. A mafic-rich enclave measuring approximately 10 × 10 × 10 cm, thought to be a partially reacted and disaggregated xenolith, can be observed within the sample. Mineralogically, the enclave contains 30% K-feldspar, 10% quartz, 20% plagioclase and 20–30% biotite. Geochemically, the sample is typical of Lina granite with high silica (75.7 wt-%) and low Fe_2O_3 and MgO (Table 2). The thorium content (18 ppm) is quite low for a Lina granite, but within the expected range.

ANALYTICAL RESULTS AND INTERPRETATION OF GEOCHRONOLOGICAL DATA

Zircons were obtained from a density separate of crushed sample using a Wilfley water table. Magnetic minerals were removed with a hand magnet. Hand-picked crystals were mounted in transparent epoxy resin together with chips of the reference zircon 91500. The zircon mounts were polished and, after gold coating, examined by back scatter electron (BSE) and cathodoluminescence (CL) imaging using the electron microscope at Evolutionsbiologiskt Centrum EBC, Uppsala University, and at the Swedish Museum of Natural History in Stockholm. High-spatial resolution secondary ion mass-spectrometer (SIMS) analysis was carried out in November and December 2014 using the Cameca IMS 1280 at the Nordsim facility of the Swedish Museum of Natural History in Stockholm.

Table 1. Summary of sample data.

Rock type:	Granite
Tectonic domain:	Svecokarelian
Lithotectonic domain:	Norrbotten
Stratigraphic or lithodemic unit:	Lina suite
Sample number:	GMS130022A
Lab-id:	n5167
Coordinates:	7366630/707545 (Sweref 99TM)
Map sheet:	736-70-11 (Sweref), 26J Jokkmokk 3 e (RT90)
Locality:	Slättkullen
Project:	Barents regional

Figure 2. Sample GMS130022A showing (on the right) typical Lina granite features. On the left is a more mafic zone, thought to be a disaggregated and partially resorbed xenolith.

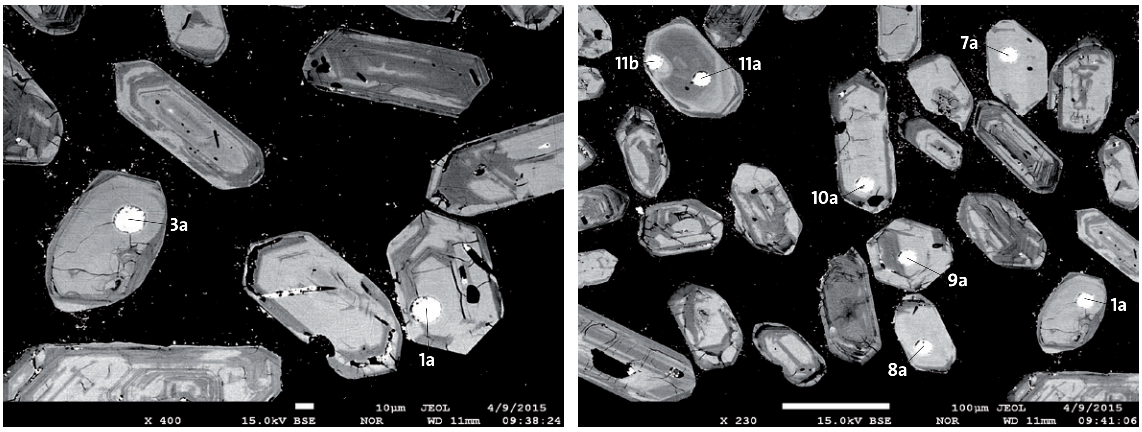
Table 2. Whole rock geochemistry by near total digestion and ICP-MS analysis. Major element concentrations in wt.% and trace elements contents in ppm.

Sample	GMS130022A
Location (Sweref 99)	7366630N, 707545E
SiO_2	75.0
Al_2O_3	12.85
Fe_2O_3	1.1
CaO	0.37
MgO	0.32
Na_2O	2.37
K_2O	6.74
Cr_2O_3	<0.01
TiO_2	0.12
MnO	0.01
P_2O_5	0.04
SrO	0.02
BaO	0.15
C	0.04
S	0.01
LOI	0.52
Total	**99.61**

Sample	GMS130022A
Ba	1285
Cr	<10
Cs	2.24
Ga	12.8
Hf	5
La	26
Nb	2.8
Rb	183.5
Sn	1
Sr	158
Ta	0.3
Th	18
Tl	0.7
U	1.25
V	6
W	1
Y	7.4
Zr	177
Ce	65.4
Pr	5.55
Nd	18.2
Sm	3.09
Eu	0.47
Gd	2.03
Tb	0.27
Dy	1.46
Ho	0.28
Er	0.86
Tm	0.1
Yb	0.79
Lu	0.1

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 calibrated relative to the Geostandards reference zircon 91500, which has an age of c. 1065 Ma (Wiedenbeck et al. 1995, 2004). In cases where the ^{204}Pb count rate was above the detection limit, common Pb corrected isotope values were calculated using the modern common Pb composition (Stacey & Kramers 1975) and measured ^{204}Pb. Decay constants follow the recommendations of Steiger & Jäger (1977). Diagrams and age calculations of isotopic data were made using the Isoplot 4.15 software (Ludwig 2012). All age uncertainties are presented at the 2σ confidence level. After analysis, BSE-imaging of the dated zircons was performed using electron microscopy at the Department of Geology, Uppsala University to confirm where the analytical spot was located on each crystal.

The heavy mineral separate from GMS139922A contains highly turbid, probably metamict zircons with abundant microfractures and mineral inclusions, i.e. of poor quality for analytical purposes. BSE images of the zircons show a blurred oscillatory zonation, mainly outlined by dark grey, metamict zones within the crystal (Fig. 3). The zircons have a weak pink colour and subhedral to euhedral, prismatic crystal shapes. The uranium content of analysed zircon is rather uniform, 557–877 ppm, except analysis no 11a that has 72 ppm uranium (Table 3). Th/U ratios are 0.34–0.78, but analysis 11b placed in a rim domain records a low value of 0.07.



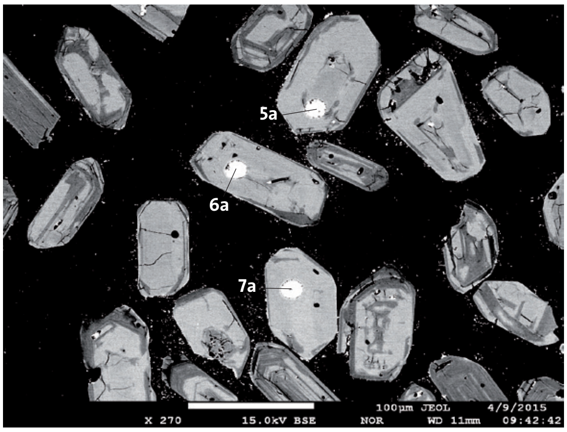


Figure 3. Back-scatter electron (BSE) images of analysed zircon grains. White spots mark the locations of analyses. Numbers refer to analytical spot number in Table 2.

A core analysis of a subhedral zircon with rounded edges (no 3a) records an older age of 1881±4 Ma, compared with the remaining analyses (Fig. 4). This zircon is thought to have been inherited from the source rock. Excluding one discordant analysis (no 9a), the remaining eight analyses record a concordia age of 1790±5 Ma (95% confidence, MSWD of concordance = 0.75, probability of concordance = 0.39), which is identical with the weighted average $^{207}Pb/^{206}Pb$ age of 1790±7 Ma (95% conf., MSWD = 2.7, probability = 0.008, n = 8). The concordia age 1790±5 Ma is chosen as the best age estimate and is interpreted as the date of igneous crystallisation of the granite at 1.79 Ga.

DISCUSSION AND CONCLUSION

The concordia age, based on 8 out of 10 analysed spots, of 1790±5 Ma confirms that the dated granite belongs to the Lina suite and helps define the age of the suite in this area. One older inherited zircon core was identified with an age of 1881±4 Ma, a ubiquitous age for Proterozoic bedrock in the region. While this result does not preclude the presence of Archean crust at depth in this area, as suggested by the ε_{Ndi} data of Mellqvist et al. (1999), it does suggest that the source of the Lina granite here is, at least in part, the Proterozoic bedrock. The presence of a large amount of metamict and poor quality zircon does, however, preclude a more definitive conclusion.

Table 3. SIMS U-Pb-Th zircon data (GMS130022A, laboratory id n5167).

Analysis	U (ppm)	Th (ppm)	Pb (ppm)	Th/U calc.[1]	^{207}Pb/ ^{235}U	±σ (%)	^{208}Pb/ ^{232}Th	±σ (%)	^{238}U/ ^{206}Pb	±σ (%)	^{207}Pb/ ^{206}Pb	±σ (%)	ρ^2	Disc. % conv.[3]	Disc. % 2σ lim.[4]	^{207}Pb/^{206}Pb age (Ma)	±σ	^{206}Pb/^{238}U age (Ma)	±σ	^{206}Pb/^{204}Pb measured	f_{206}%[5]
n5167_01a	691	452	284	0.66	4.726	1.05	0.0936	2.64	3.175	1.02	0.1088	0.25	0.97	−1.0		1780	5	1765	16	22562	0.08
n5167_03a	557	192	225	0.34	5.267	1.00	0.0975	3.43	3.012	0.97	0.1151	0.25	0.97	−2.0		1881	4	1848	16	99432	0.02
n5167_05a	693	428	285	0.62	4.821	1.00	0.0926	2.12	3.140	0.97	0.1098	0.23	0.97	−0.9		1796	4	1782	15	43358	0.04
n5167_06a	671	454	283	0.70	4.823	1.04	0.0953	2.12	3.100	0.98	0.1084	0.34	0.94	1.9		1773	6	1802	15	16267	0.11
n5167_07a	781	615	331	0.78	4.777	1.04	0.0920	2.86	3.162	1.01	0.1096	0.25	0.97	−1.3		1792	4	1771	16	117799	0.02
n5167_08a	570	319	234	0.58	4.850	1.08	0.0955	2.09	3.111	1.05	0.1094	0.25	0.97	0.5		1790	5	1797	16	200737	{0.01}
n5167_09a	877	507	269	0.46	3.507	3.55	0.0708	5.68	4.166	3.46	0.1060	0.76	0.98	−22.1	−15.6	1731	14	1387	43	12269	0.15
n5167_10a	662	395	269	0.59	4.797	0.96	0.0923	4.16	3.156	0.93	0.1098	0.25	0.97	−1.4		1796	4	1774	14	190599	{0.01}
n5167_11a	72	41	29	0.54	4.883	1.27	0.0893	2.30	3.124	1.05	0.1106	0.71	0.83	−1.2		1810	13	1790	16	47909	{0.04}
n5167_11b	574	54	209	0.07	4.878	1.26	0.0731	12.76	3.099	1.22	0.1096	0.31	0.97	0.6		1793	6	1803	19	11891	0.16

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.
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.

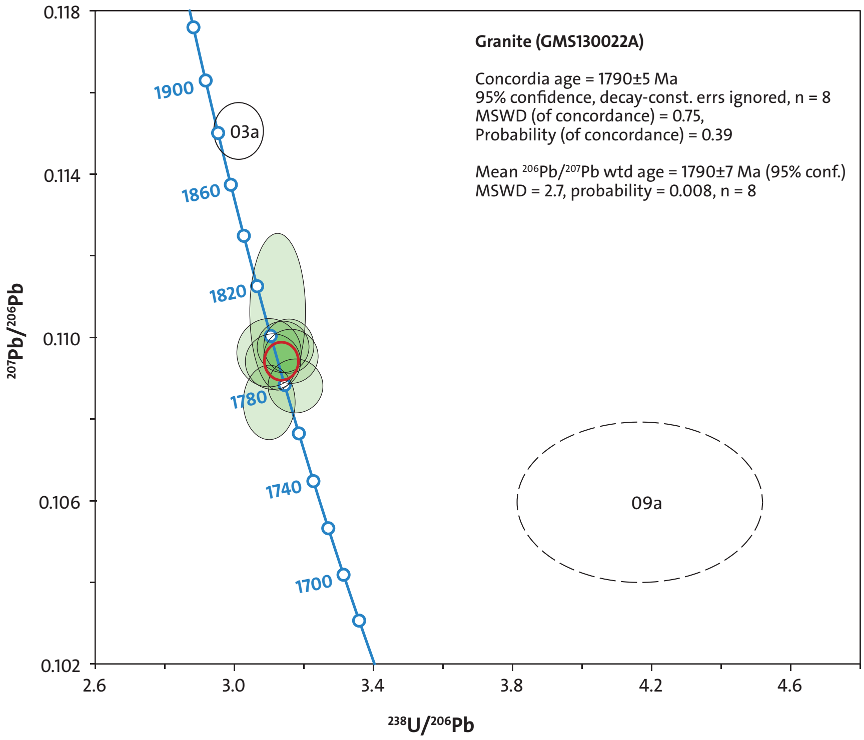


Figure 4. Tera Wasserburg diagram showing U-Pb SIMS data of zircon analyses of GMS130022A. The discordant analysis 9a is shown with broken line. Analysis 3a is thought to represent an inherited zircon. Error ellipse of calculated weighted mean age is shown in red.

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