# U–Pb zircon SIMS-geochronology of a migmatitic sandstone of the Snavva–Sjöfallet group north of Arjeplog, Norrbotten County

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Cover: Granitic veins in migmatitic sandstone of the Snavva–Sjöfallet group, eastern shore of Lake Skierfajaure, c. 250 m north of the dating locality.
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# ABSTRACT

U–Pb radiometric analyses (SIMS) of zircon rims from a decimetre wide, folded vein of cordierite and sillimanite bearing pegmatitic leucosome yielded a poorly determined age of c. 1.76 Ga, which is interpreted to date a late Svecokarelian metamorphic event in the rocks of the Snavva–Sjöfallet group. Analyses of oscillatory zircon core domains in the Skierfajaure sample record ages at c. 2.7 Ga, 1.98 Ga and 1.89 Ga, and the analysed crystals are interpreted as detrital zircon material. The youngest age group at c. 1.89 Ga gives a maximum age of deposition of the Snavva–Sjöfallet group.

***Keywords:*** Snavva–Sjöfallet group, migmatitic sandstone, leucosome, metamorphic event, maximum age, U–Pb, zircon, geochronology.

# SAMMANFATTNING

Radiometriska U–Pb analyser (SIMS) av zirkonkanter från en decimeterbred, veckad ådra av cordierit- och sillimanitförande pegmatitisk leukosom har gett en dåligt bestämd ålder av ca 1,76 miljarder, som tolkas att datera en sensvekokarelsk metamorfoshändelse som drabbat bergarterna i Snavva–Sjöfallsgruppen. Analyser av oscillatoriska domäner av zirkonkärnor har givit åldrar som ligger omkring 2,7, 1,98 och 1,89 miljarder år. De analyserade kristallerna uppfattas som detritiskt zirkonmaterial, och den yngsta åldersgruppen runt 1,89 miljarder år ger en maximumålder för avsättningen av Snavva–Sjöfallsgruppen.

***Nyckelord:*** Snavva–Sjöfallsgruppen, migmatitisk sandsten, leukosom, metamorfoshändelse, maximumålder, U–Pb, zirkon, geokronologi.

# INTRODUCTION

The Snavva–Sjöfallet group (cf. Ödman 1957; Zachrisson & Witschard 1995a, 1995b; Kumpulainen 2003; Bergman & Kathol 2018) occurs as a mainly north–south trending, c. 160 km long belt of sedimentary rocks between Lake Kakirjaure in the north and Lake Hornavan in the south. The southern part of this belt forms the bedrock in the central and eastern parts of map areas 26H Jäkkvik NO and SO (Figs. 1, 2) and 25H Arjeplog NO. The Snavva–Sjöfallet group comprises sandstones, arkoses, greywackes and slates which in places are metamorphosed at different degrees to paragneisses, schists and mica schists. In general, the metamorphic grade within the Snavva–Sjöfallet group increases towards the south from almost unaltered sandstones at Stora Sjöfallet in the north to migmatites in the area around Lake Skierfajaure southeast of Lake Tjeggelvas. Within the map areas 26H Jäkkvik NO and SO, low grade rocks alternate with high grade, migmatised sedimentary rocks. Sillimanite and cordierite are common in the latter rocks.

The aim of this study is by dating of zircons in the leucosome of the migmatised rocks to determine the age of the metamorphic event or events that led to growth of cordierite, garnet and sillimanite and partly migmatisation within the rocks of the Snavva–Sjöfallet group.

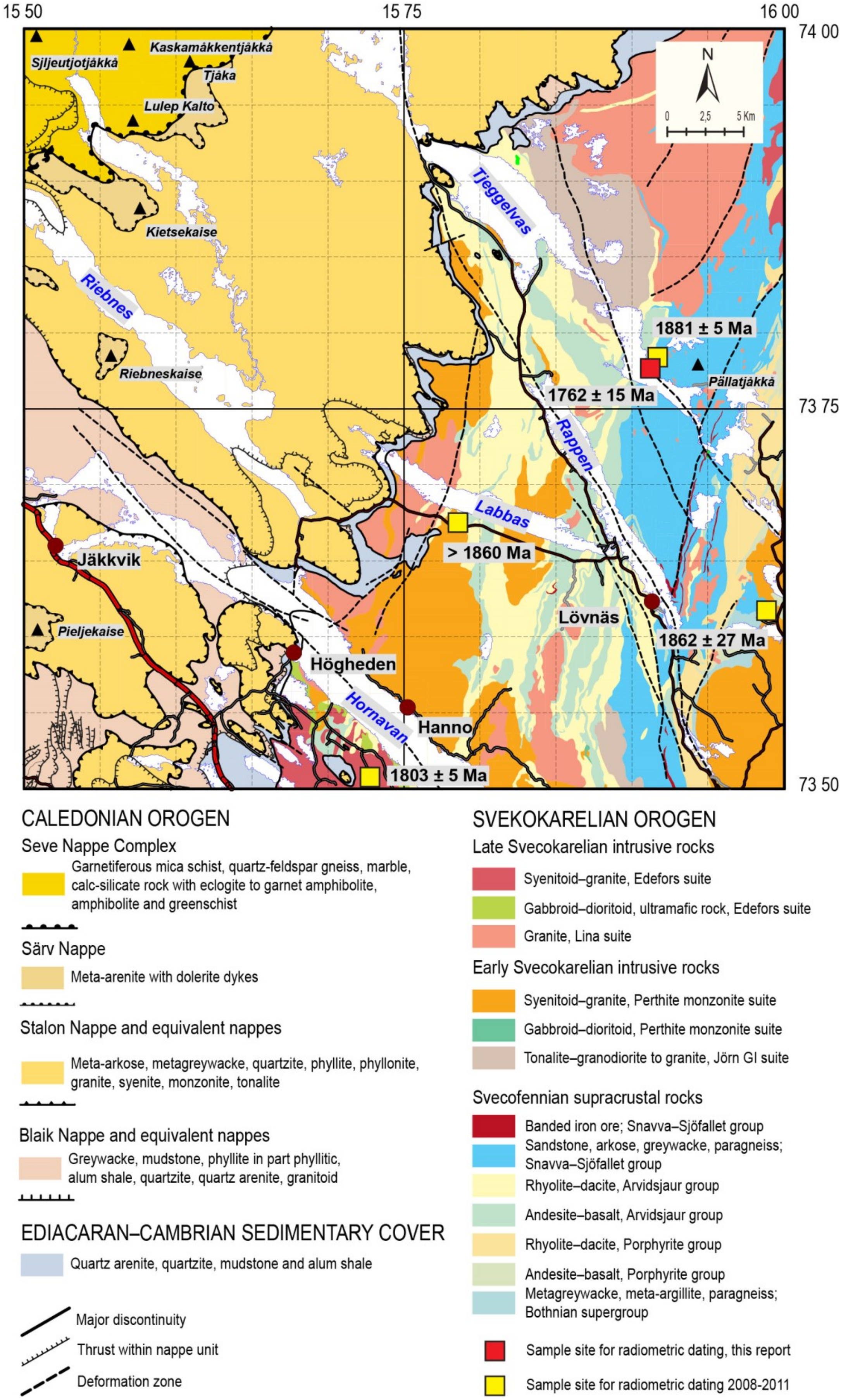


**Figure 1.** Geological map over the map area 26H Jäkkvik taken from the 1:50 000 and 1:250 000 bedrock databases of the SGU. The map is simplified in the area of the Ediacaran–Cambrian sedimentary cover and the Caledonian orogen.

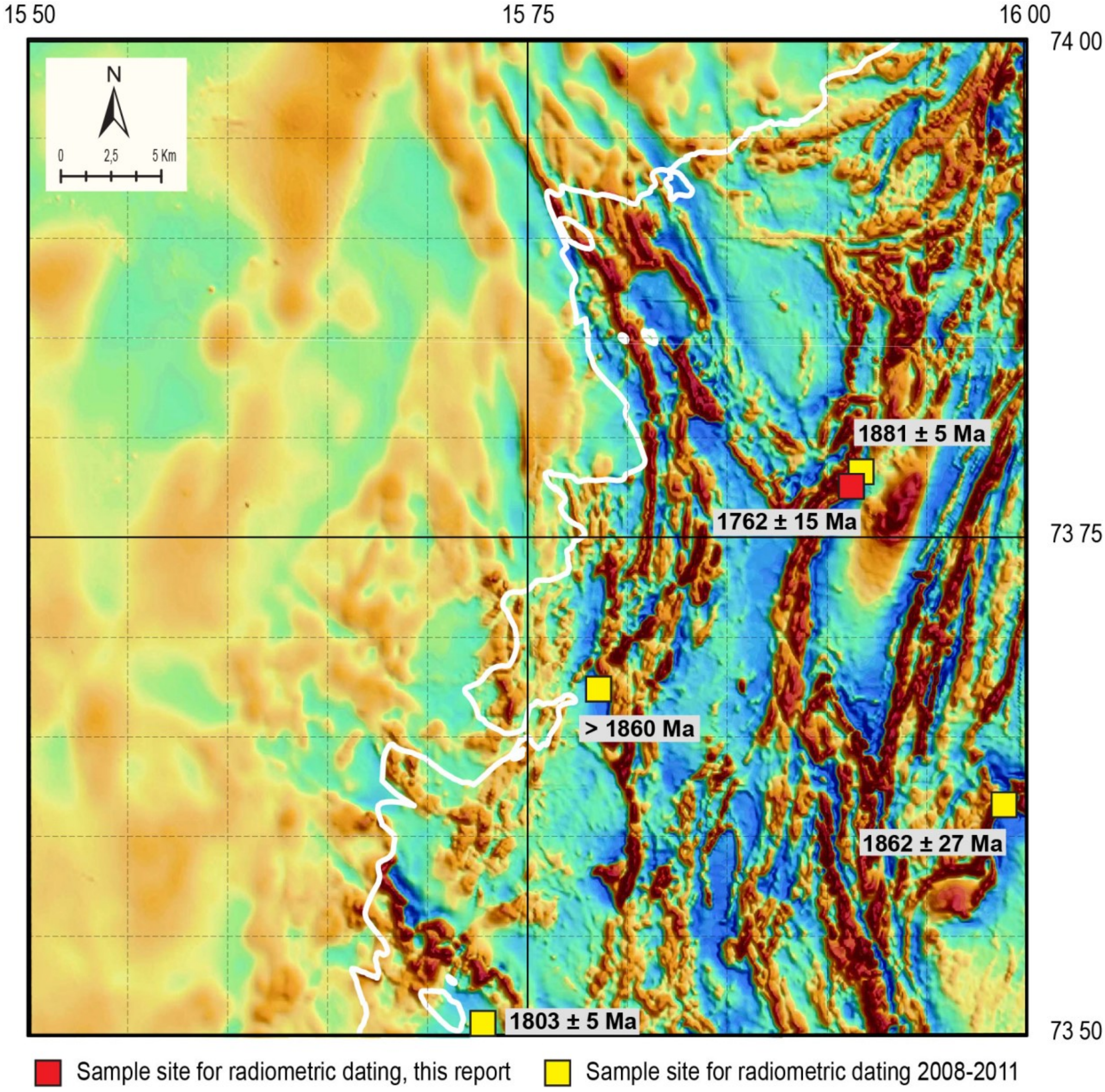


**Figure 2.** Magnetic anomaly map over the map area 26H Jäkkvik. Red colours: high magnetic anomalies, blue colours: low magnetic anomalies. The white line shows the easternmost extension of the Ediacaran–Cambrian sedimentary cover and the Caledonian orogen.

## SAMPLE DESCRIPTION

The sample has been collected from a small outcrop at the northeastern shore of Lake Skierfajaure, c. 3.4 km to the west of Mt. Pällatjåkkå (Table 1). The main rock in this outcrop is a recrystallised, layered, foliated and folded sandstone (Fig. 3a), belonging to the Snavva–Sjöfallet group. This sandstone contains up to some decimetre wide, in parts folded veins of cordierite and sillimanite bearing pegmatitic leucosome, which have been the subject for the sampling (Fig. 3b). The pegmatite veins locally truncate the layering and the foliation within the sandstone.

**Table 1.** Summary of age sample data

| | |
|---|---|
| **Rock type** | Migmatitic sandstone |
| **Tectonic domain** | Svecokarelian orogen |
| **Tectonic subdomain** | Bothnia-Skellefteå lithotectonic unit |
| **Stratigraphic unit** | Svecofennian supracrustal rocks |
| **Lithostratigraphic unit** | Snavva–Sjöfallet group |
| **Sample number** | SPN110220X |
| **Lab-id** | n4389 |
| **Coordinates (SWEREF 99 TM)** | 7376878/626793 |
| **Map sheet (SWEREF 99 TM)** | 737-62-11 |
| **Map sheet (RT90)** | 26H Jäkkvik 5g |
| **Locality** | Skierfajaure, c. 3.4 km west of Mt. Pällatjåkkå |
| **Project** | Barents |

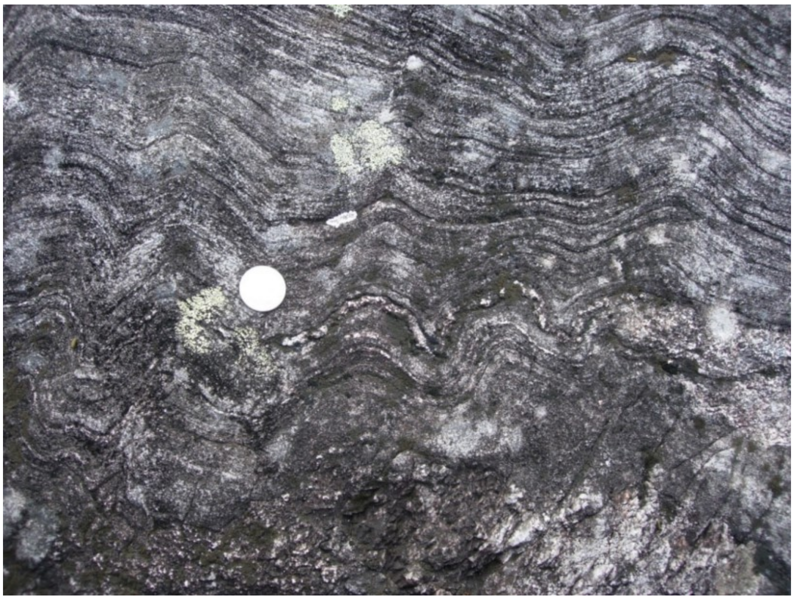

**Figure 3A.** Layered, foliated and folded migmatitic sandstone of the Snavva–Sjöfallet group. Eastern shore of Lake Skierfajaure, c. 3.4 km to the west of Mt. Pällatjåkkå. (SWEREF 99 TM; 7376878/626793). Photo: Stefan Persson.

**Figure 3B.** The dated sample of a pegmatitic leucosome vein material in the sandstone. Eastern shore of Lake Skierfajaure, c. 3.4 km to the west of Mt. Pällatjåkkå. (SWEREF 99 TM; 7376878/626793). Photo: Stefan Persson.

# ANALYTICAL RESULTS AND INTERPRETATION OF GEOCHRONOLOGICAL DATA

Zircons were obtained by density separation 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 standard electron microscopy at the Evolutionary Biology Centre (EBC) and after SIMS-analyses at the Department of Geology, Uppsala University.

High-spatial resolution secondary ion masspectrometer (SIMS) analysis was done in December 2012 using a Cameca IMS 1270 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). Pb/U 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. Decay constants follow the recommendations of Steiger & Jäger (1977). Diagrams and age calculations of isotopic data were made using software Isoplot 3.00 (Ludwig 2012).

There is plenty of zircon in the heavy mineral separate. Most grains have subhedral prismatic shapes, some are euhedral. Microcracks are common in most grains. BSE-images reveal an oscillatory zonation (Fig. 4). In some grains there are irregular BSE-bright rim domains. Most analyses show high values of common lead. Core analyses generally have higher Th/U ratios (0.08–0.45) compared to analyses of BSE-bright rim domains (Table 2). Two of rim analyses (56, 7r) have Th/U ratios of 0.12 and 0.08, but BSE-images show that the locations of these analyses seem to include also some core material (Fig. 4). The other rim analyses have Th/U ratios of 0.01–0.02. The Uranium content is 114–828 ppm for core analyses and 563–859 ppm for rim analyses. Analysis 35c is 18% discordant with an apparent $^{207}$Pb/$^{206}$Pb age at c. 2.65 Ga indicating Archean material in the sample (Figs. 5a, b). Analysis 2c and 7c are concordant or near concordant (0.0%, 3.7% reversely discordant) with a weighted $^{207}$Pb/$^{206}$Pb average age at 1976 ± 11 Ma (MSWD = 0.50, probability = 0.48). 57c could possibly also be included in this age group but is 17.5% discordant ($^{207}$Pb/$^{206}$Pb age = 1954 ± 36 Ma, 2σ). Analyses 1 and 56r2 are -3.3 and 4.0% discordant with a $^{207}$Pb/$^{206}$Pb weighted average age at 1889 ± 7 Ma (MSWD = 3.7, probability = 0.055).

Rim analyses show all except 44r high values of common lead and are highly discordant. 7r, 56, 79r, 91r record f206 >1.1% and are excluded from age calculation. 7r, 56, 79r and 91r can also be excluded based on the spot location in the BSE-images as these analyses seem to include some core material. The remaining three rim analyses (44r, 67r, 64r) are 2.2%, 13.9% and 14.5% discordant, respectively. A discordia through these three points give upper and lower intercepts at 1762 ± 15 and 312 ± 150 Ma (95 % conf.; MSWD = 0.082; Fig. 5b). As the discordia line is based on only three points where two of the data points are almost equal, the calculated intercept ages are of dubious reliability.

To sum up, analyses of oscillatory zircon core domains record ages at c. 2.7 Ga, 1.98 Ga and 1.89 Ga. Although a very limited dataset, the spread in ages suggests detrital zircon material. The youngest age group at c. 1.89 Ga gives a maximum age of deposition of the sedimentary precursor. The upper intercept age at 1762 ± 15 Ma of BSE-bright rim domains is interpreted to date migmatisation of the sandstone at c. 1.76 Ga. However, based on only three, discordant data points, the given metamorphic age is uncertain and need to be constrained with more analyses.

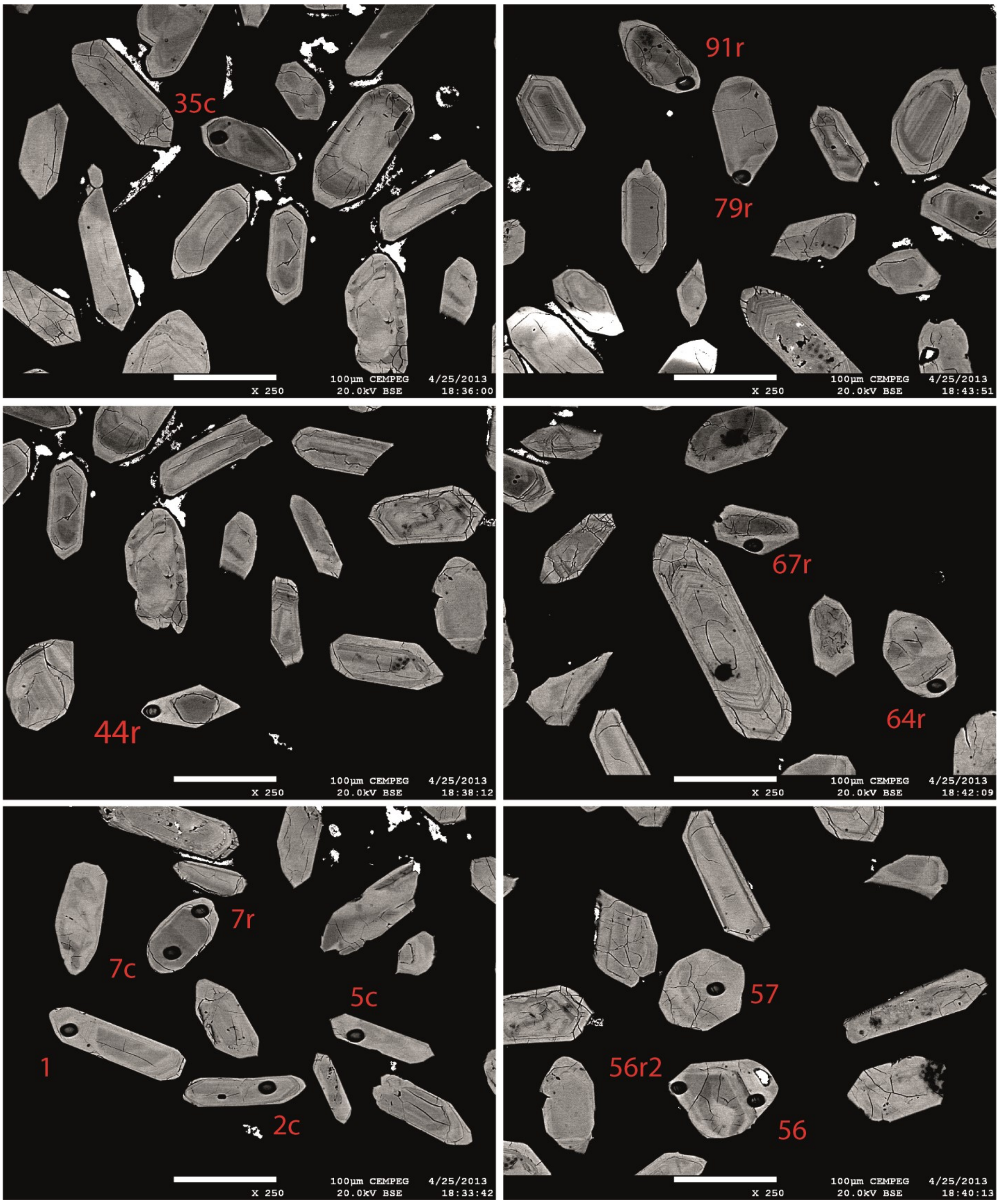


**Figure 4.** BSE-images of zircon grains. Numbers refer to analytical spot number in Table 2.

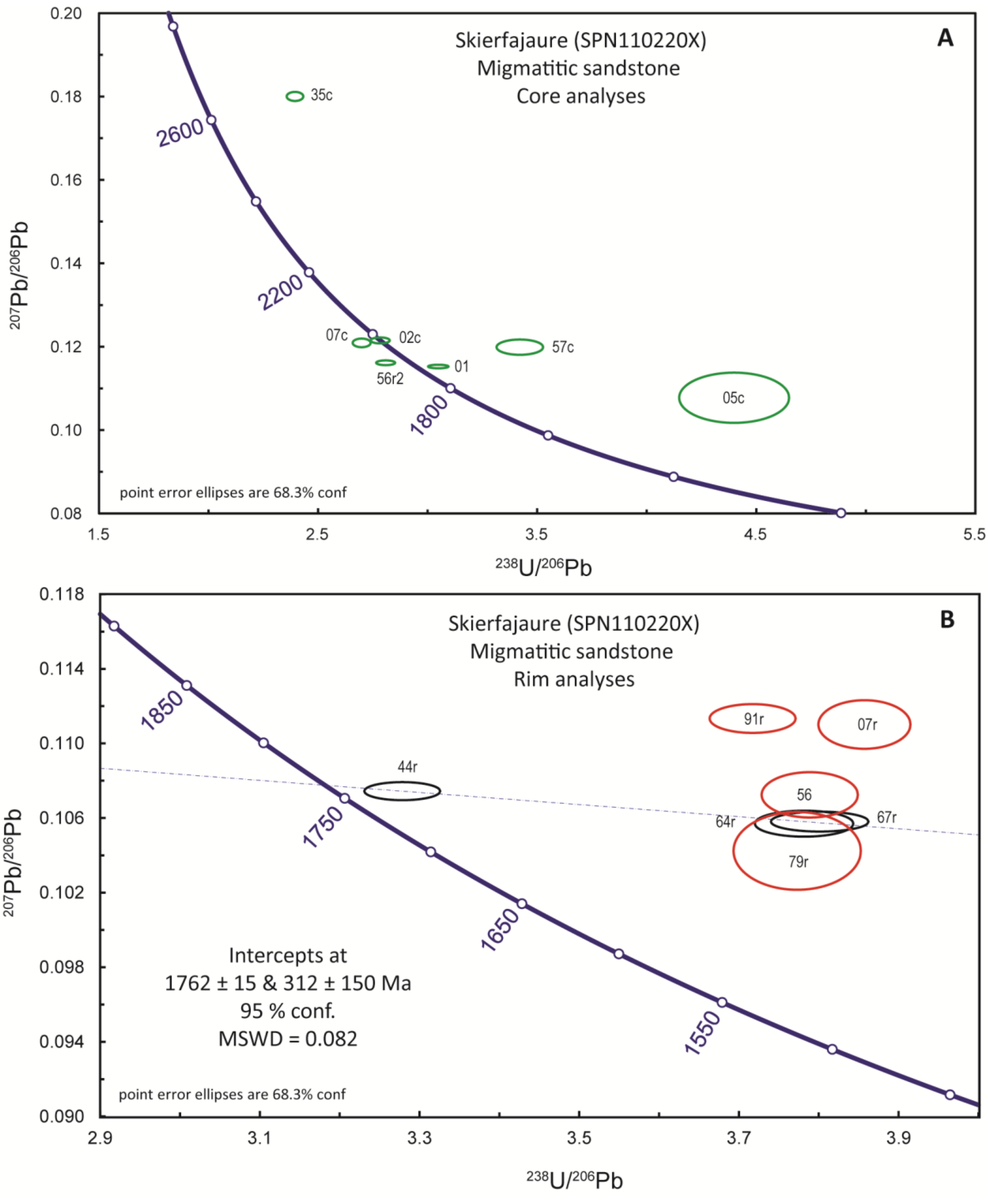


**Figure 5.** Tera Wasserburg diagram showing U–Pb SIMS data of zircon analyses from a migmatitic sandstone of the Snavva–Sjöfallet group. **A.** Core analyses of crystals interpreted as detrital zircon material in green. **B.** Rim analyses used for age calculation are shown in black, excluded analyses in red (see text for explanation).

**Table 2**. SIMS U–Pb–Th zircon data (SPN110220X).

| Anal. spot | Comment | Conc. (ppm) U | Th | Pb | Th/U[1] calc | Isotopic ratios $^{207}Pb/^{235}U$ | ±σ % | $^{238}U/^{206}Pb$ | ±σ % | $^{207}Pb/^{206}Pb$ | ±σ % | $^{206}Pb/^{204}Pb$ | ρ[2] | $f_{206}$%[3] | Disc. %[4] conv. | Disc. %[5] 2σ lim. | Calculated ages (Ma) $^{207}Pb/^{206}Pb$ | ±σ | $^{206}Pb/^{238}U$ | ±σ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| n4389-01 | core | 714 | 232 | 283.3 | 0.31 | 5.212 | 1.04 | 3.049 | 1.01 | 0.1152 | 0.24 | 9444 | 0.97 | 0.20 | -3.3 | -1.1 | 1884 | 4 | 1829 | 16 |
| n4389-02c | core | 233 | 20 | 96.0 | 0.08 | 6.018 | 1.10 | 2.784 | 1.03 | 0.1215 | 0.39 | 17434 | 0.94 | 0.11 | 0.0 | | 1978 | 7 | 1979 | 18 |
| n4389-05c | core | 828 | 172 | 219.6 | 0.15 | 3.377 | 5.27 | 4.399 | 3.76 | 0.1077 | 3.69 | 516 | 0.71 | 3.62 | -27.7 | -9.7 | 1762 | 66 | 1320 | 45 |
| n4389-07c | core | 114 | 47 | 52.2 | 0.43 | 6.177 | 1.15 | 2.699 | 1.00 | 0.1209 | 0.57 | 137988 | 0.87 | {0.01} | 3.7 | 0.4 | 1970 | 10 | 2032 | 17 |
| n4389-35c | core | 224 | 123 | 123.8 | 0.43 | 10.365 | 1.12 | 2.395 | 1.04 | 0.1800 | 0.40 | 1503 | 0.93 | 1.24 | -18.0 | -15.7 | 2653 | 7 | 2250 | 20 |
| n4389-56r2 | core | 554 | 257 | 246.4 | 0.48 | 5.702 | 1.06 | 2.809 | 1.01 | 0.1161 | 0.32 | 7637 | 0.95 | 0.24 | 4.0 | 1.4 | 1898 | 6 | 1963 | 17 |
| n4389-57c | core | 547 | 306 | 204.1 | 0.45 | 4.832 | 2.28 | 3.421 | 2.05 | 0.1199 | 1.01 | 2169 | 0.90 | 0.86 | -17.5 | -11.8 | 1954 | 18 | 1653 | 30 |
| n4389-07r | rim (mix with core) | 603 | 52 | 178.2 | 0.08 | 3.968 | 1.25 | 3.857 | 0.99 | 0.1110 | 0.77 | 805 | 0.79 | 2.32 | -20.3 | -16.4 | 1816 | 14 | 1486 | 13 |
| n4389-44r | rim | 728 | 18 | 247.1 | 0.02 | 4.519 | 1.00 | 3.278 | 0.96 | 0.1074 | 0.30 | 4685 | 0.95 | 0.40 | -2.6 | -0.3 | 1756 | 5 | 1716 | 14 |
| n4389-56 | rim (mix with core) | 563 | 129 | 170.8 | 0.12 | 3.903 | 1.29 | 3.789 | 1.05 | 0.1072 | 0.75 | 1343 | 0.81 | 1.39 | -15.5 | -11.6 | 1753 | 14 | 1510 | 14 |
| n4389-64r | rim | 713 | 18 | 208.6 | 0.02 | 3.838 | 1.11 | 3.801 | 1.06 | 0.1058 | 0.33 | 2764 | 0.95 | 0.68 | -14.5 | -12.0 | 1728 | 6 | 1506 | 14 |
| n4389-67r | rim | 859 | 26 | 252.3 | 0.01 | 3.854 | 1.16 | 3.782 | 1.07 | 0.1057 | 0.44 | 1876 | 0.93 | 1.00 | -13.9 | -11.1 | 1727 | 8 | 1512 | 15 |
| n4389-79r | rim (mix with core) | 845 | 22 | 248.6 | 0.02 | 3.809 | 1.92 | 3.773 | 1.39 | 0.1042 | 1.32 | 953 | 0.73 | 1.96 | -12.2 | -5.5 | 1701 | 24 | 1516 | 19 |
| n4389-91r | rim (mix with core) | 647 | 114 | 195.3 | 0.03 | 4.130 | 1.06 | 3.717 | 0.96 | 0.1113 | 0.46 | 1628 | 0.90 | 1.15 | -17.6 | -15.0 | 1821 | 8 | 1536 | 13 |

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] Percent 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, and indicate a value calculated assuming present-day Stacey-Kramers common Pb.

[4] Age discordance in conventional concordia space. Positive numbers are reverse discordant.

[5] Age discordance at closest approach of error ellipse to concordia (2σ level).

## DISCUSSION AND CONCLUSION

The upper intercept age of 1762 ± 15 Ma, obtained from analyses of zircon rims, is interpreted to date a late Svecokarelian metamorphic event with migmatisation of the sandstones and other sedimentary rocks of the Snavva–Sjöfallet group at 1.76 Ga. However, this age is based on only three data points and must be considered with caution. More and better analyses of secondary zircon rim domains from this and other leucosome samples would be desirable to better constrain the age interval for this metamorphic event in the Snavva–Sjöfallet group.

Similar ages, taken as representing metamorphic events have been reported from several places and different rock types in the Bothnia–Skellefteå lithotectonic unit. In the north central part of map area 25I Stensund NV, a grey to dark grey, fine-grained gneiss has been interpreted as a migmatised intermediate volcanic rock. This rock has been dated at Alep Tjåhkålis c. 25 km northeast of Arjeplog, and the obtained age of c. 1780 Ma (Hellström in preparation-a) is construed to date a metamorphic event in this area, post-dating the emplacement of the protolith with at least 80 million years.

Two titanite samples from quartz veins, hosted in a quartz-monzodiorite in the ore zone of the Björkdal gold mine northwest of Skellefteå plot nearly concordantly at $^{207}Pb/^{206}Pb$ ages of respectively 1783 ± 22 Ma and 1793 ± 14 Ma (Billström et al. 2009), and the ages are interpreted to indicate a metamorphic event which post-dates the intrusion of the host rock with more than one hundred million years.

Metagreywackes in the Piteå area are migmatised and contain abundant veins, dykes and smaller massifs of migmatite granite. This granite also in turn contains numerous inclusions of older, mainly supracrustal rocks. A sample from a three metres wide homogeneous granite dyke was dated by U–Pb method on monazite and yielded a crystallisation age of 1784 ± 5 Ma (Kathol & Weihed 2005). Also, in this case, the time span between the deposition of the greywackes and the metamorphic event, indicated by the forming of the migmatite granite is roughly 100 million years. A time constraint for the deposition of the greywackes is given by the minimum age of the uppermost part of the sedimentary sequence, a conglomerate in the Piteå area, which is defined by age determinations of a granodiorite pebble in the conglomerate and a cross-cutting tonalitic dyke at 1868 ± 13 Ma and 1865 +24/-10 Ma respectively (Persson & Lundquist 1997).

At first glance, the 1.76 Ga metamorphic event, described here from the Lake Skierfajaure area, gives a rough minimum age for the lithification of the sedimentary sequence of the Snavva–Sjöfallet group. However, field relationships where the sampled veins locally truncate the layering and foliation in the sandstone indicate that the rocks of the Snavva–Sjöfallet group have been the subject for at least one deformation phase, which predates the metamorphic event at c. 1.76 Ga.

Another age constraint for the Snavva–Sjöfallet group is given by the c. 1.78 Ga old Hárreválrddo intrusion which split the sedimentary sequence of the Snavva–Sjöfallet group into a northern and a southern part. Thus, the undeformed Hárreválrddo intrusion provides a minimum age of c. 1.78 Ga (Claeson & Antal Lundin 2013, 2019) for deposition and deformation of the Snavva–Sjöfallet group.

Taking the poor quality of the age determination with only three discordant data points in account, it could also be possible that the younger metamorphic event at Lake Skierfajaure and elsewhere can be related to the intrusion of felsic magmas, forming the Hárreválrddo and other, minor intrusions of the Edefors and Lina suites in the area.

Analyses of oscillatory zircon core domains in the Skierfajaure sample record ages at c. 2.7 Ga, 1.98 Ga and 1.89 Ga. Although the dataset is very limited, the spread in ages suggests that the analysed crystals are detrital zircon material. The youngest age group at c. 1.89 Ga gives a maximum age of deposition of the sampled horizon of the Snavva–Sjöfallet group. This is corroborated by U–Pb age determinatons on zircon of c. 1.89–1.88 Ga, obtained in volcanic rocks of either the Arvidsjaur or the Porphyrite group (Hellström in preparation-b; Kathol & Hellström 2020). However, the maximum age for at least the northern part of the group is even better defined by the age of underlying volcanic rocks, dated at Hårås to 1872 ± 9 Ma (Nysten et al. 2018).

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Hellström in preparation-b: Age of the rhyolitic host rock to the Skuppesavon uranium mineralisation in the Arjeplog area, northern Sweden. *SGU-rapport*, Sveriges geologiska undersökning.