U–Pb zircon age of a rhyolite from Mt. Tjåresvare north of Arjeplog, Norrbotten County

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Cover: View from Mt. Tjåresvare over Lake Tjeggelvas and the Caledonian front.
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ABSTRACT

U–Pb radiometric analyses (SIMS) of zircon grains of a rhyolite from Mt. Tjåresvare yielded an age of 1881 ± 5 Ma, which is interpreted as the crystallisation age of the rhyolite. This age does not give an explicit stratigraphic affiliation of the volcanic rocks, situated to the west of the Snavva–Sjöfallet group and north of Lake Hornavan to either the Porphyrite group or the Arvidsjaur group. Due to field relationships, these rocks are assigned to the Arvidsjaur group. They represent the oldest, lowermost parts of the Arvidsjaur group and not a northern continuation of the younger subunit of the Arvidsjaur group in the Bure–Makkavare area.

Keywords: Rhyolite, U–Pb, zircon, geochronology, Arvidsjaur group, Porphyrite group.

SAMMANFATTNING

Radiometriska U–Pb analyser (SIMS) av zirkonkristaller hos en ryolit från Tjåresvare har gett en ålder av 1881 ± 5 miljoner år som tolkas som ryolitens kristallisationsålder. Den här åldern ger dock ingen klar information om att vulkaniterna som förekommer väster om Snavva–Sjöfallsgruppen och norr om Hornavan ska räknas till Porfyritgruppen eller till Arvidsjaurgruppen. På grund av fält-relationer hänförs de här bergarterna till Arvidsjaurgruppen. De representerar den äldsta, undre delen av Arvidsjaurgruppen och inte en nordlig fortsättning av den yngre underenhet i Arvidsjaur-gruppen som förekommer i Bure–Makkavare-området.

Nyckelord: Ryolit, U–Pb, zirkon, geokronologi, Arvidsjaurgruppen, Porfyritgruppen

INTRODUCTION

The bedrock in large areas in southwestern Norrbotten and northwestern Västerbotten Counties consists of Svecofennian subaerial volcanic rocks, which in the southern part of that area have been assigned to the 1.88–1.86 Ga Arvidsjaur group (Lundberg 1980; Weihed et al. 1992; Allen et al. 1996; Kathol & Weihed 2005).

During mapping of map area 25J Moskosel in southern Norrbotten County, the existence of terrestrial subaerial volcanic rocks older than the 'classic' Arvidsjaur group rocks was indicated by field relationships and indirectly by the 1882 ± 8 Ma age of a granodiorite intrusion of the Jörn GI suite, which truncates the volcaniclastic sequence of the Abmo peninsula (Falk 1973) at Övre Ljusselet (Kathol & Persson 2007a). Supported by a dating of a coherent rhyodacite in the volcaniclastic sequence itself, which yielded an age of 1880 ± 6 Ma (Kathol et al. 2008a), Hartvig & Aaro (2012a, 2012b) and Kathol & Aaro (2012) consequently distinguished an older group from the 1.88–1.86 Ga Arvidsjaur group and denominated it 'Svecofennian supracrustal rocks, c. 1.90–1.88 (–1.86?) Ga'.

Later, under the mapping program of the SGU in the southwestern Norrbotten County, volcanic rocks in the Luvos and Jokkmokk map areas have recorded c. 1.89–1.88 Ga U–Pb zircon ages (Hellström & Berggren 2014, Claeson et al. 2018), i.e. higher than the ages of the 'classic' Arvidsjaur group. Also, in southeastern Norrbotten County, U–Pb zircon dating of a rhyolite from Stasskölhuvudet, southwest of Gunnarsbyn and a rhyolite to dacite from Grassmyrberget, east of Boden both yielded ages in the time interval 1.89–1.88 Ga (Sadeghi & Hellström 2015).

The obtained 1.89–1.88 Ga ages confirm the existence of a magmatic arc older than the arc that formed the volcanic rocks of the Arvidsjaur group, which in southern Norrbotten County have been dated at Benbryteforsen (Kathol & Persson 2007b), Danielstugan (Kathol et al. 2008b), Tjappisvare (Claeson & Antal Lundin 2012), Makkavare (Morris et al. 2015), Hårås (Nysten et al. 2018) and at Kaddåive, Kallak, Rimpos, Stora Samonåive and as well at Savvemoajvve within the time interval 1.88–1.86 Ga (1.89–1.86 Ga when errors are taken into account).

Therefore, Bergman & Kathol (2018) divided the Svecofennian volcanic rocks of the southern Norrbotten County area into the 1.88–1.86 Ga 'classic' Arvidsjaur group (1.89–1.86 Ga when errors are taken into account) and the slightly older but overlapping 1.89–1.88 Ga Porphyrite group (1.90–1.87 Ga when errors are taken into account). This has been done as an attempt to link the stratigraphy of the volcanic rocks in southern Norrbotten County with those in northern Norrbotten County (Bergman et al. 2001 and references therein), though Bergman & Kathol (2018) state, that the characterisation of the Arvidsjaur and Porphyrite groups in terms of compositional variations, depositional settings and ages needs to be improved, and that establishing the relationships to the Kiirunavaara group (Martinsson 2004) in the north is also required.

As there still is no available age of Svecofennian volcanic rocks to the west of the Snavva–Sjöfallet group in the western part of the southern Norrbotten County map area (Bergman & Kathol 2018), dating of the rhyolite from Mt. Tjåresvare (Figs. 1, 2; Table 1) would give information about the affiliation of these mainly subaerial volcanic rocks. These rocks might either belong to the Porphyrite group or to the Arvidsjaur group. If these rocks are assigned to the latter group, the dating will also give information about whether they represent a northern continuation of the Bure formation (Perdahl 1995; Perdahl & Einarsson 1994; Skiöld et al. 1993) which is interpreted as a young subunit of the Arvidsjaur group by Morris et al. (2015), or an older unit within the Arvidsjaur group.

SAMPLE DESCRIPTION

The sample has been collected from a rhyolite in a small outcrop at the southwestern slope of Mt. Tjåresvare, c. 3.3 km to the west-northwest of Mt. Pällatjåkkå (Figs. 1, 2; Table 1). The sampled rock is a feldspar-porphyritic, foliated and recrystallized volcaniclastic rhyolite (Fig. 3a, b). In a TAS-diagram (Le Bas et al. 1986), the sampled rhyolite plots in the rhyolite field close to the border to the trachyte–trachydacite field. Magnetic susceptibility values vary between 1,500 and 3,100 × 10^{-5} SI units. The red colour indicates that the rhyolite has been deposited under subaerial conditions. Subaerial deposition is indicated by eutaxitic textures and lithophysae, occurring at several places in the felsic volcanic rocks both east and west of the sedimentary belt of the Snavva–Sjöfallet group.

Table 1. Summary of age sample data

Rock type	Rhyolite
Tectonic domain	Svecokarelian orogen
Tectonic subdomain	Bothnia–Skellefteå lithotectonic unit
Stratigraphic group	Svecofennian supracrustal rocks
Lithostratigraphic unit	Arvidsjaur group
Sample number	SPN110237A
Lab-id	n4390
Coordinates (SWEREF 99TM)	7377901/627101
Map sheet (SWEREF 99TM)	737-62-11
Map sheet (RT90)	26H Jäkkvik 5g
Locality	Mt. Tjåresvare, c. 3.3 km to the west-northwest of Mt. Pällatjåkkå
Project	Barents

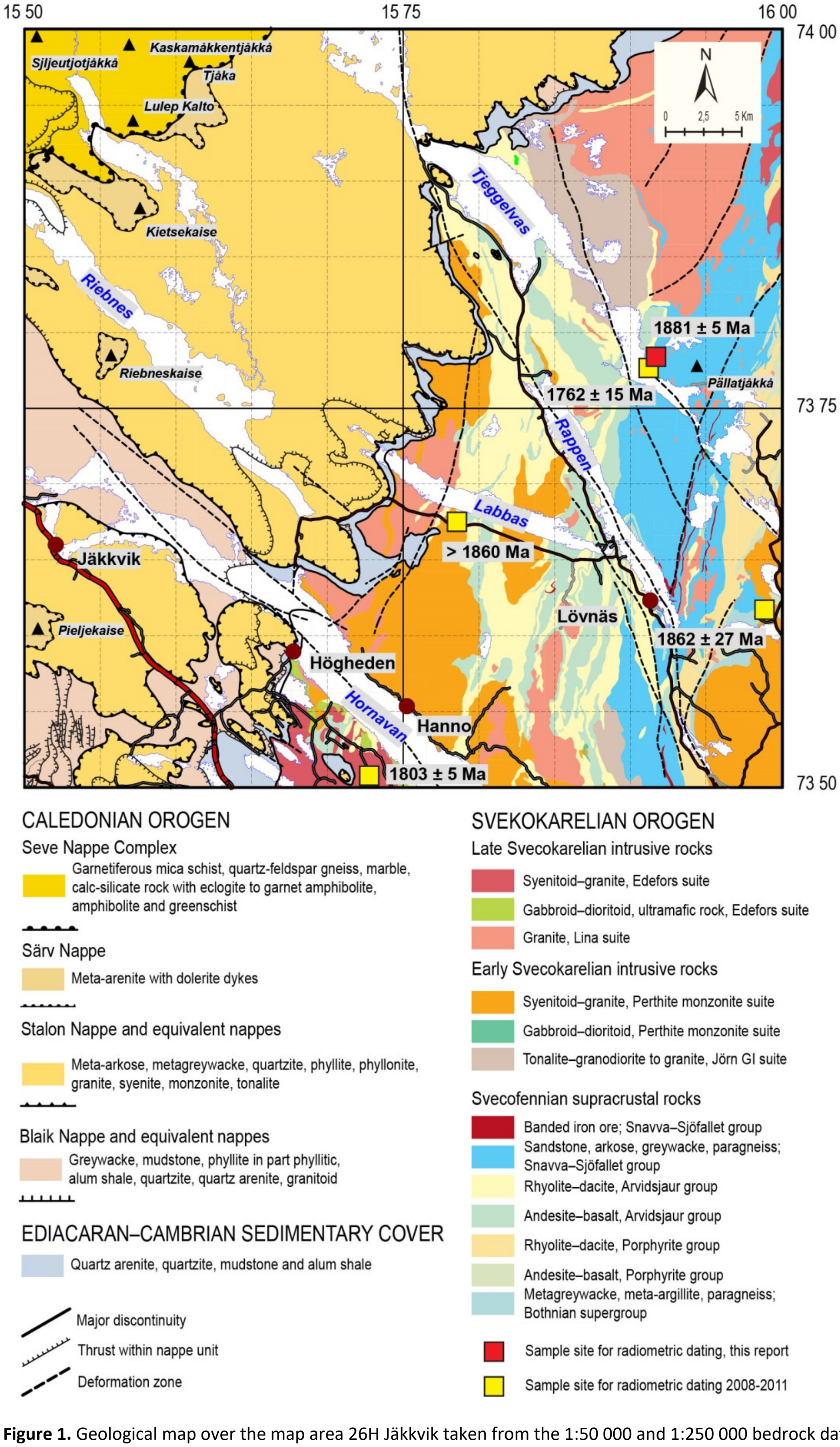

Figure 1. Geological map over the map area 26H Jäkkvik taken from the 1:50 000 and 1:250 000 bedrock databases of the SGU. The map is simplified in the area of the Ediacaran–Cambrian sedimentary cover and the Caledonian orogen.

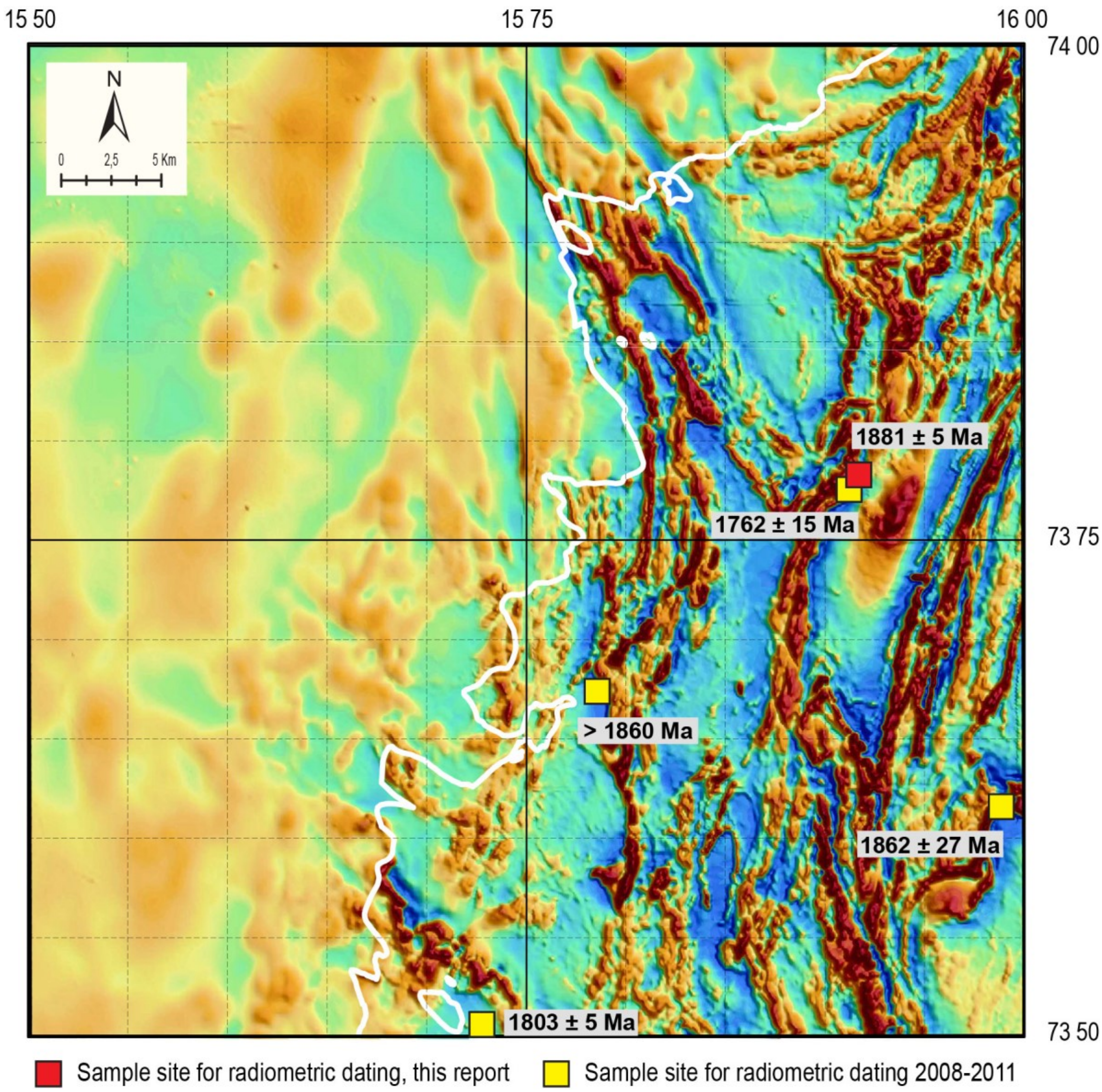

Figure 2. Magnetic anomaly map over the map area 26H Jäkkvik. Red colours: high magnetic anomalies, blue colours: low magnetic anomalies. The white line shows the easternmost extension of the Ediacaran–Cambrian sedimentary cover and the Caledonian orogen.

Figure 3A. Feldspar-porphyritic, recrystallized, volcaniclastic rhyolite from the sampling site at the southwestern slope of Mt. Tjåresvare, c. 3.3 km west–northwest of Mt. Pällatjåkkå, weathered surface. (SWEREF 99 TM; 7377901/627101). Photo: Stefan Persson.Kort om kartor.

Figure 3B. Feldspar-porphyritic, recrystallized, volcaniclastic rhyolite from the sampling site at the southwestern slope of Mt. Tjåresvare, c. 3.3 km west–northwest of Mt. Pällatjåkkå, unweathered surface. (SWEREF 99 TM; 7377901/627101). Photo: Stefan Persson.

ANALYTICAL RESULTS AND INTERPRETATION OF GEOCHRONOLOGICAL DATA

Zircons were obtained by a 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), 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). BSE and Cathodoluminescence (CL)-imaging was also done after SIMS-analyses at the Department of Geology, Uppsala University.

The heavy mineral separate is rich in zircon. Most zircon grains are turbid to transparent, weakly pinkish and have subhedral, prismatic crystal shapes. There are also anhedral, rounded grains. BSE/CL-images show an internal oscillatory zonation in most zircons, in some grains only weakly developed (Fig. 4). There are possibly inherited cores in a few grains. Other grains have a homogenous BSE-CL level or show irregular BSE/CL-dark and bright domains within the same grain. Analyses 37r and 57 are placed in BSE-bright, secondary domains (Fig. 4). These two analyses record lower Th/U ratios (0.02–0.09) compared with the oscillatory zoned core analyses (0.20–0.52). The Uranium content is 108–416 ppm for core analyses and 216–412 ppm for the secondary domain analyses (Table 2). The BSE-bright, secondary analyses are both reversely discordant, 10.0% and 11.6%. Analysis 37r is somewhat older than 57, still younger than the core analyses. However, the analysis 37r seems according to the post-analysis BSE-image to overlap with the core domain, i.e. this analysis possibly represents a mixed age between primary and secondary age components. 37r also has a higher Th/U ratio (0.09) compared with analysis no 57 (0.02). Apparent ^{207}Pb/^{206}Pb ages are 1794 ± 20 Ma (2σ; 37r) and 1745 ± 12 Ma (2σ; 57), but due to the high degree discordance this just give an indication of a secondary age somewhere at 1.75–1.80 Ga. Eight of the remaining ten oscillatory zoned core analyses are concordant at the 2σ level with a Concordia age at 1881 ± 5 Ma (MSWD of concordance = 0.13, probability of concordance=0.72, n = 8; Fig. 5). The weighted average ^{207}Pb/^{206}Pb age is 1880 ± 5 Ma (MSWD = 0.38, probability = 0.92), i.e. identical to the Concordia age. The Concordia age is chosen as the best age estimate interpreted to date igneous crystallization of the rhyolite at c. 1.88 Ga.

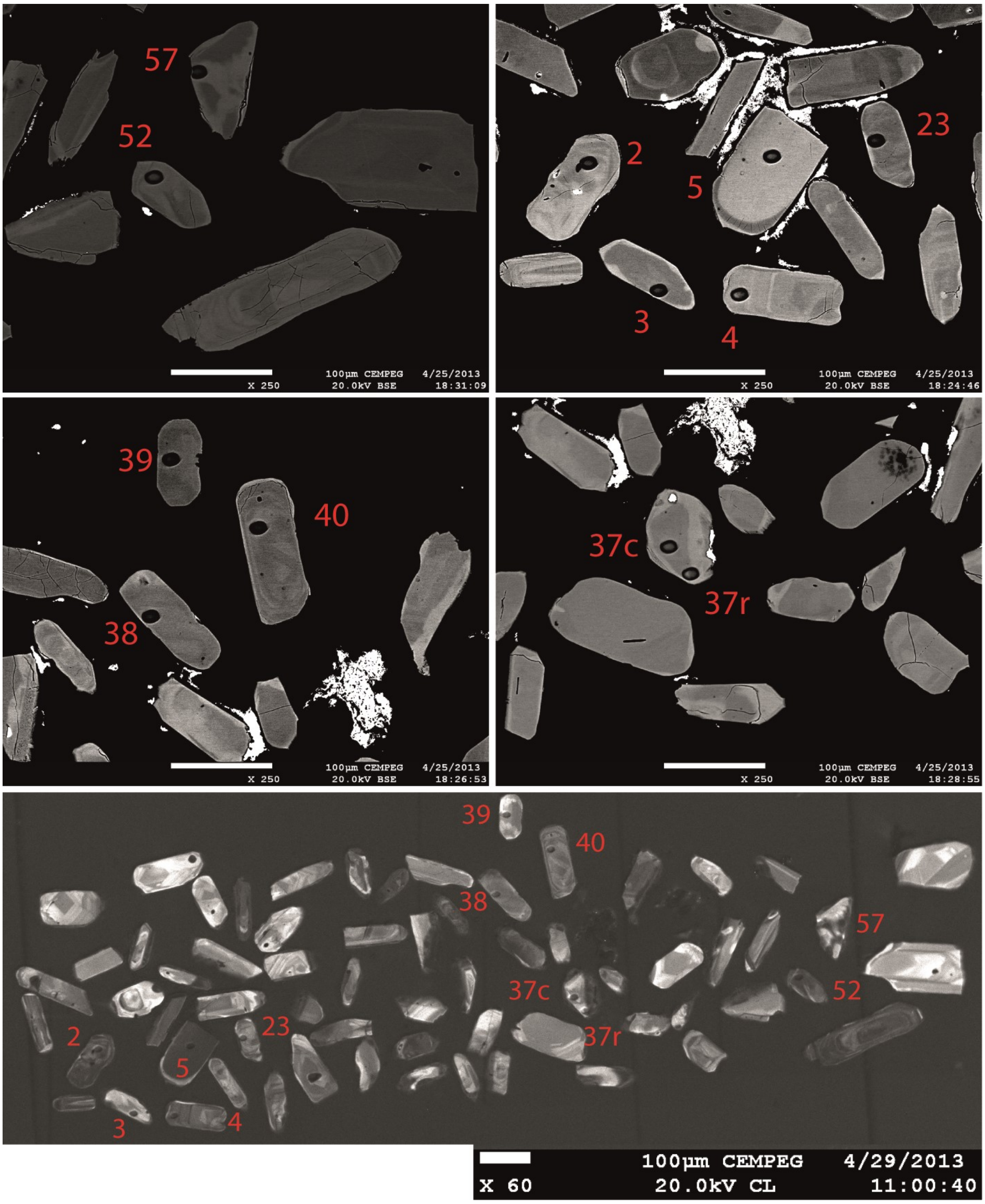

Figure 4. BSE-images in the upper part and CL-image in the lower part show analysed zircon grains. Numbers refer to analytical spot number in Table 2.

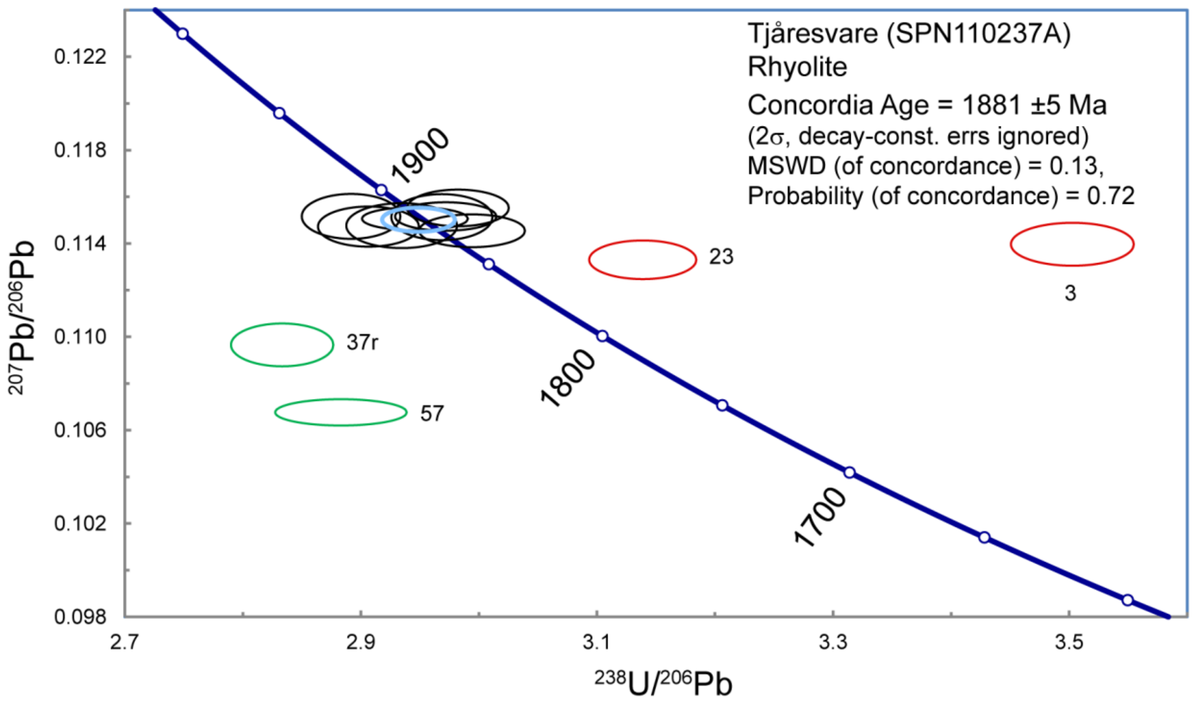

Figure 5. Tera Wasserburg diagram showing U–Pb SIMS data of zircon analyses from a rhyolite from Mt. Tjåresvare north of Arjeplog. Analyses used in age calculation are marked in black, excluded analyses in red and analyses of secondary BSE-bright domains in green. Error ellipse of calculated weighted mean age is shown in light blue.

Table 2. SIMS U–Pb–Th zircon data (SPN110237A).

					Isotopic ratios								Age (Ma)			
Sample/ Spot#	U ppm	Th ppm	Pb ppm	Th/U calc[1]	^{238}U/^{206}Pb	±σ %	^{207}Pb/^{206}Pb	±σ %	^{206}Pb/^{204}Pb	f_{206}%[2]	Disc % conv.[3]	Disc % 2σ lim.[4]	^{207}Pb/^{206}Pb	±σ	^{206}Pb/^{238}U	±σ
n4390-02	229	55	91	0.24	2.982	0.95	0.1155	0.45	10018	0.19	-1.5		1888	8	1864	15
n4390-03	157	64	55	0.32	3.503	0.98	0.1140	0.53	10408	0.18	-14.8	-11.9	1864	10	1619	14
n4390-04	278	83	111	0.30	2.994	0.99	0.1145	0.41	119770	{0.02}	-0.9		1873	7	1858	16
n4390-05	416	176	174	0.42	2.946	1.00	0.1151	0.28	130139	0.01	0.2		1881	5	1884	16
n4390-23	169	39	63	0.20	3.139	0.95	0.1133	0.48	11933	0.16	-4.3	-1.5	1853	9	1783	15
n4390-37c	140	60	60	0.44	2.906	0.97	0.1147	0.49	>1e6	{0.00}	1.9		1876	9	1906	16
n4390-37r	216	23	87	0.09	2.833	1.01	0.1097	0.55	35347	0.05	10.0	6.5	1794	10	1949	17
n4390-38	188	74	80	0.40	2.892	0.95	0.1152	0.55	162358	{0.01}	2.0		1882	10	1915	16
n4390-39	108	55	46	0.52	2.935	1.06	0.1148	0.55	56802	{0.03}	0.9		1876	10	1890	17
n4390-40	180	63	74	0.34	2.969	0.95	0.1151	0.57	203987	{0.01}	-0.6		1882	10	1871	15
n4390-52a	354	145	147	0.41	2.972	0.95	0.1152	0.35	157394	{0.01}	-0.8		1882	6	1870	15
n4390-57a	412	22	159	0.02	2.883	1.27	0.1068	0.35	8640	0.22	11.6	8.3	1745	6	1919	21

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 Pbcom assuming a single stage of closed U-Th-Pb evolution.
[2] 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.
[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).

DISCUSSION AND CONCLUSION

The obtained age of 1881 ± 5 Ma does not give an explicit stratigraphic affiliation of the rhyolite from Mt. Tjåresvare to either the Porphyrite group or the Arvidsjaur group. However, despite the slightly higher age than 1880 Ma, we have chosen to assign this rhyolite and the Svecofennian volcanic rocks to the west of the southern part of the Snavva–Sjöfallet group to the Arvidsjaur group. This is due to overall field relationships between felsic volcanic rocks and granites, assigned to the 1.89–1.85 Ga Perthite monzonite suite (Kathol et al. 2010; Hellström et al. 2015; Kathol & Hellström 2015; Sarlus et al. 2017; Kathol & Hellström 2018), which in other areas is coeval and comagmatic with the Arvidsjaur group (Kathol & Weihed 2005 and references therein). In the map area 26H Jäkkvik SO, this relationship is supported by magma mingling structures between inclusions of coherent volcanic rocks and the surrounding granite which have been observed c. 30 km south-southeast of Mt. Tjåresvare in the contact area between granite and felsic volcanic rocks to the east of Hanno (Fig. 1; Kathol et al. 2010).

The obtained age also implies that the volcanic rocks west of the Snavva–Sjöfallet group and north of Lake Hornavan cannot be considered as a northern continuation of the Bure formation (Perdahl 1995; Perdahl & Einarsson 1994; Skiöld et al. 1993), interpreted by Morris et al. (2015) as a younger subunit of the Arvidsjaur group. The felsic and mafic volcanic rocks in the map area 26H Jäkkvik to the west of the Snavva–Sjöfallet group rather represent the oldest, lowermost parts of the Arvidsjaur group. This difference in age also supports the existence of a major structural break in the bedrock below Lake Hornavan as postulated by Kathol & Hellström (2015).

The border between the Porphyrite group in the east, and the Arvidsjaur group in the west (of the Snavva–Sjöfallet group) must be situated somewhere below the Snavva–Sjöfallet group (Fig. 1), because the maximum age for the latter group, defined by the age of underlying volcanic rocks, dated at Hårås to 1872 ± 9 Ma (Nysten et al. 2018), is significantly lower than the ages obtained from volcanic rocks in direct vicinity east and west of the Snavva–Sjöfallet group at Skuppesavon (Hellström in preparation) and Mt. Tjåresvare. This relationship in time between the three groups requires an unconformity at the base of the Snavva–Sjöfallet group.

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