Age of the rhyolite hosting the Ultevis Mn-Fe-Ba-As mineralisation, northern Sweden

Per Nysten, Per-Olof Persson, Fredrik Hellström
& George A. Morris

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Cover: Tjatjisvare at the Mn-mineralisation in rhyolite. Seitevare dam and Hårås hill with the dating locality in the central far background.
Photographer: Per Nysten

Authors: Per Nysten, Per-Olof Persson, Fredrik Hellström & George A. Morris
Reviewed by: Benno Kathol
Responsible head of division: Ildikó Antal Lundin
Project: Barents regional

Geological Survey of Sweden
Sveriges geologiska undersökning
Box 670, 751 28 Uppsala
tel: 018-17 90 00
fax: 018-17 92 10
e-post: sgu@sgu.se

www.sgu.se

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ABSTRACT

A feldspar-porphyric Svecofennian rhyolite associated with Mn-mineralisations at Ultevis, west of Jokkmokk, northern Sweden, has been dated to 1872 ± 9 Ma. This figure also gives a maximum age of deposition of the stratigraphically overlaying sedimentary rock sequence (the Snavva–Sjöfall group). The position of Mn-Fe-Ba-As-F-U-(W-Mo) mineralisations is discussed in relation to the transition from volcanic to sedimentary environments in the Tjåmotis–Ultevis area.

***Keywords**:* U-Pb zircon geochronology, volcanic rock, Ultevis, Mn-mineralisation, Svecofennian, Svecokarelian orogen, Fennoscandian shield

SAMMANFATTNING

En fältspatporfyrisk, Svekofennisk ryolit som är associerad med Mn-mineraliseringar i Ultevis, väster om Jokkmokk, norra Sverige, har daterats till 1872 ± 9 Ma. Denna siffra ger också en maximal ålder för avsättning av den stratigrafiskt överlagrade sedimentära bergartssekvensen (Snavva–Sjöfallgruppen). Mn-Fe-Ba-As-F-U- (W-Mo) mineraliseringarnas position diskuteras i relation till övergången från vulkaniska till sedimentära miljöer i Tjåmotis–Ultevis-området.

***Nyckelord**:* U-Pb zirkon geokronologi, vulkaniska bergarter, Ultevis, Mn-mineralisering, svekofennium, svekokarelska orogenen, fennoskandiska skölden

INTRODUCTION

Volcanic rocks (basalt–andesite and dacite–rhyolite) cover large areas of the western parts of Norrbotten County in northern Sweden, as shown by recent bedrock mapping of the map areas 27H Kvikkjokk NO & SO, 27I Tjåmotis NV & NO and 27J Porjus NV, NO by the Geological Survey of Sweden (SGU). Within the central and westernmost parts of the map area 27I Tjåmotis NV there is a transition going from volcanic rocks in the east, into sedimentary rocks in the west (Fig. 1). Within a marble horizon, close to the contact between dacites and rhyolites of the Arvidsjaur group and paragneisses of the Snavva–Sjöfallet group, manganese (Mn) mineralisations occur intermittent over more than 20 km. This Mn-bearing zone can be followed from Aitevare and Lástak south of the Lake Tjaktjajaure via Raktennjárgga and Hårås into the Ultevis area north of the lake. Locally, high concentrations of W, Mo and U are also found (Ödman 1947, Carlon 1984). Furthermore, epigenetic (remobilized) Mn mineralisations are found within the dacites and rhyolites. The sedimentary sequence of the Snavva–Sjöfallet group was interpreted as being stratigraphically younger based on field evidence although the volcanic-sedimentary succession is locally overturned, e.g. at Rakten (Nysten et al. 2014).

Concise age determinations of the volcanic rocks are lacking from the above-mentioned mapping area but further east, in the northwestern part of the map area 27K Nattavaara NV, a felsic volcanic rock has been dated at 1868 ± 6 Ma (Claeson & Antal Lundin 2012), suggesting an age affinity to the 1.88–1.87 Ga volcanic rocks of the Arvidsjaur group. Furthermore, older volcanic rocks are most probably present locally**,** as suggested by 1.89–1.88 Ga U-Pb zircon ages of felsic to intermediate metavolcanic rocks in the south-western Norrbotten County (e.g. Hellström & Berggren 2014). Overall, age determinations of volcanic rocks in Norrbotten County are rare, and in order to put more time constraints on the volcanic activity, a sample of a rhyolite from the area north of Tjåmotis was chosen for U-Pb zircon dating. The sample site occurs high up in the volcanic stratigraphy adjacent to the sedimentary rocks. The obtained age will give a maximum depositional age of the sedimentary rocks of the Snavva–Sjöfallet group and it will also constrain the age of the Ultevis Mn-Fe-Ba-As mineralisation.

SAMPLE DESCRIPTION

The rhyolite sample for dating was taken from a large flat outcrop area, 100 × 50 meters in size, situated on the southern slope of Hårås (SWEREF 7444982/657294). It consists of a feldspar-porphyritic light grey, partly recrystallized and weakly banded rhyolite (Fig. 2 & 3, Table 1).

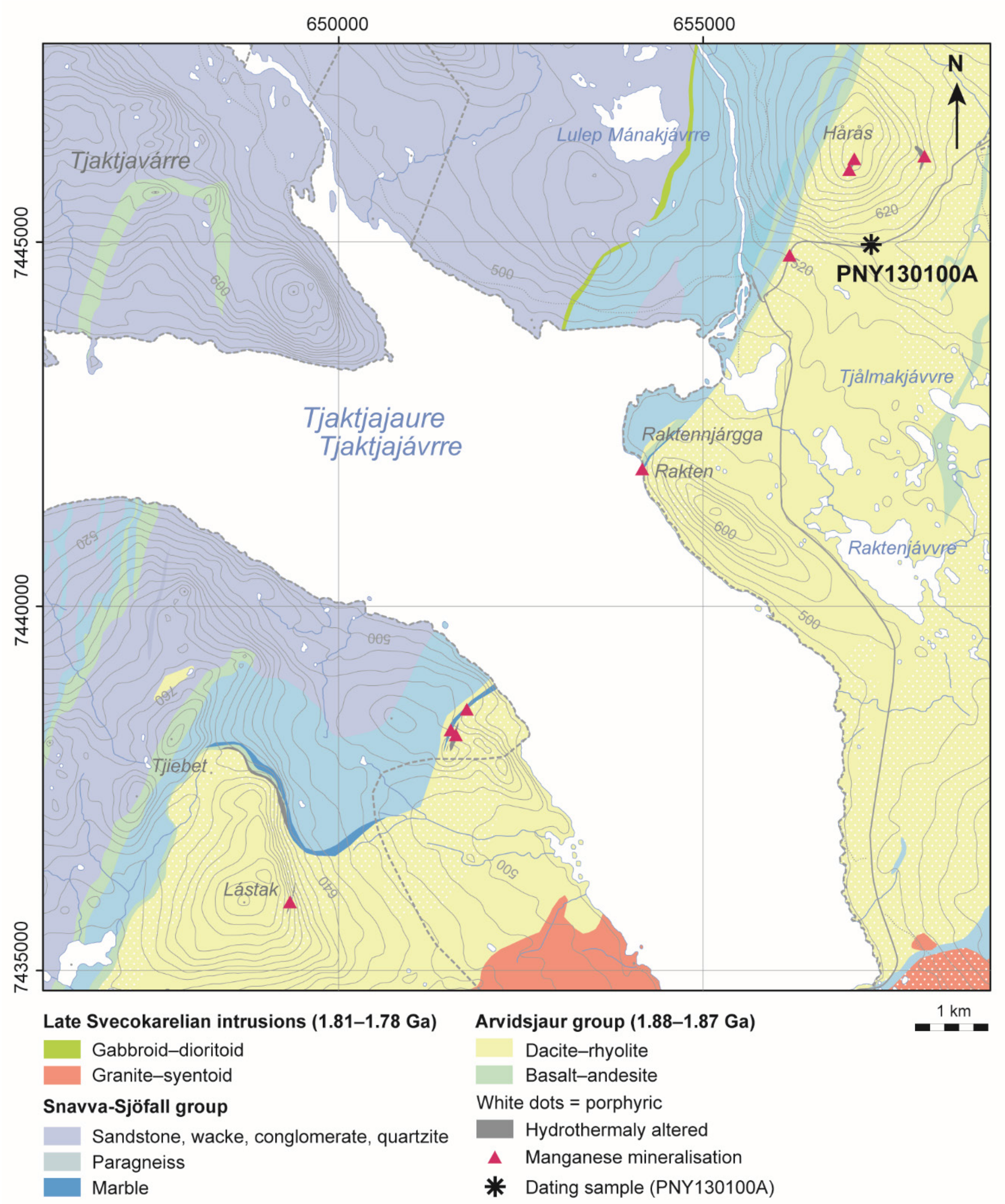

Figure 1. Geological map over the Tjaktjajaure–Ultevis area. Coordinates are given in SWEREF 99 TM.

Figure 2. Rhyolite outcrop 1 km north of the dating locality 7446053/658067 (SWEREF 99 TM.) Photo: Per Nysten.

Figure 3. Banded rhyolite from the dating locality (7444982/657294, SWEREF99TM). Size of the coin is 20 mm. Photo: Per Nysten

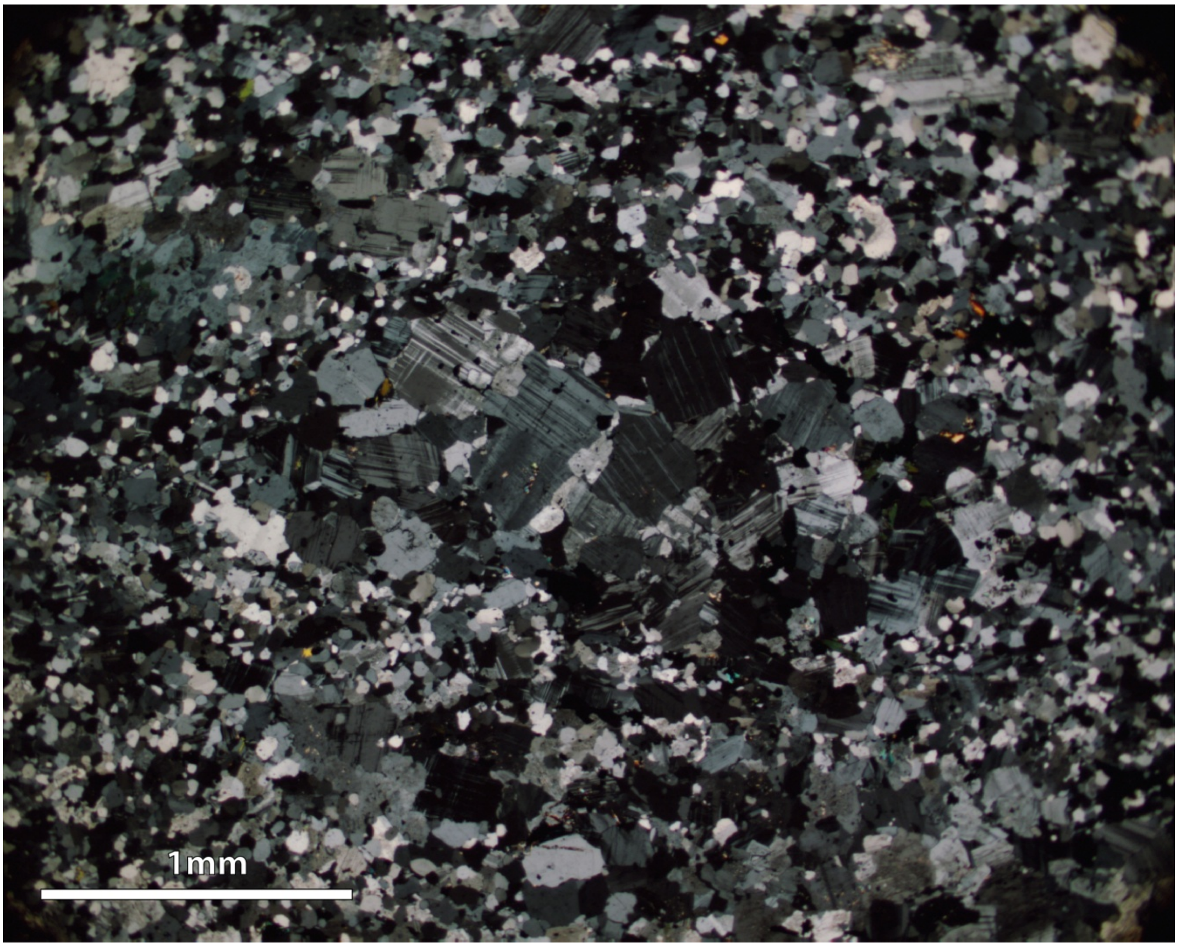

Figure 4. Recrystallised 2 × 1 mm large microcline phenocryst in a matrix of microcline, quartz and sericitised plagioclase. Transmitted light, crossed polarizers. Photo: Per Nysten.

Microcline forms white phenocrysts up to 2 × 1 millimetres in size. Microcline occurs as recrystallized phenocrysts in the form of elongated aggregates (Fig. 4). All subgrains of microcline display tartan twinning. The rock matrix consists of microcline, quartz and sericitised plagioclase showing weak to distinct albite twinning. Oligoclase compositions are suggested by measurement of plagioclase extinction angles. Rare subhedral zircon, 100 × 50 micrometers in size with multiple cores and oscillatory growth zones were observed. Anhedral, opaque oxide grains, up to one millimeter in size occur disseminated in the rock matrix. Locally, these occur concentrated into black bands and pods a few millimeters thick and several centimeters long. These oxides consist of hematite, bixbyite ($(Mn,Fe)_2O_3$) and probably braunite ($Mn^{2+}Mn^{3+}{}_6[O_8|SiO_4]$). Pale pink, manganiferous muscovite (alurgite), occurs as isolated crystals and crystal aggregates within the rock. Violet fluorite is found associated with muscovite. Thus, a certain hydrothermal overprint exists within the rhyolite. This is also manifested by coarse veins, pods and schlieren of Mn- and F-enriched pegmatites present in the vicinity of the dating locality (Fig. 5).

Figure 5. Hollandite-bearing pegmatite vein cutting feldspar-porphyritic rhyolite (7446088/ 658012, SWEREF 99 TM). Hollandite: $(Ba,K)(Mn,Ti,Fe)_8O_{16}$. Photo: Per Nysten.

Table 1. Summary of age sample data.

Rock type	**Rhyolite**
Tectonic domain	Svecokarelian orogen
Tectonic subdomain	Bothnia-Skellefteå lithotectonic domain
Stratigraphic group	Arvidsjaur group
Sample number	PNY130100A
Lab-id	n5399
Coordinates	7444982/657294 (SWEREF 99 TM)
Map sheet	27I NV (RT90)
Locality	Hårås, southern slope
Project	Kartering Barents

Feldspar phenocrysts are evenly distributed within the rock matrix. This may be interpreted as a coherent volcanic texture. Carlon (1984) includes both rhyolitic lavas and volcanoclastic lithologies within the volcanic rocks here. Especially at the locality Rakten, coarse agglomerate horizons are present. The degree of recrystallisation varies on a regional scale (100 m to km) within the same rock unit. Both strongly recrystallised varieties as well as types with 3–5 mm large perfectly euhedral microcline crystals have been noted. The Mn-bearing light grey rhyolite, was named white leptite or manganporfyr by Ödman (1947). This rock is underlain by a fine- to medium-grained, weakly feldspar- porphyritic, red metavolcanic rock to the east. This rock, which is totally devoid of Mn-minerals, was named red leptite by Ödman (1947).

ANALYTICAL RESULTS

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 carbon coating examined by Cathodoluminescence (CL) imaging using electron microscopy at the Swedish Museum of Natural History in Stockholm. Samples were then re-coated with gold. High-spatial resolution secondary ion mass spectrometer (SIMS) analysis was carried out in November 2015 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. 10–15 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. CL-imaging of the dated zircons was performed using electron microscopy at the Swedish Museum of Natural History in Stockholm.

The zircons are generally colourless, rounded or subhedral, often with black inclusions. Only a few crystals are euhedral. On the CL-images, the majority of the crystals have dark grey interior parts that often show oscillatory zoning and bright rims. The rims are often wide and the boundary between rim and interior can be smooth or irregular, sometimes with the bright rim protruding deep into the interior. Most of the analysis points are in the central, darker material. The point 8b is in the rim and 2, 9a and 12 are on the boundary. All these analyses have low U concentration, 67–99 ppm, compared to 121–291 ppm for the others. The former have also higher Th/U-ratios, 0.43–0.53, compared to 0.29–0.44 (Table 2).

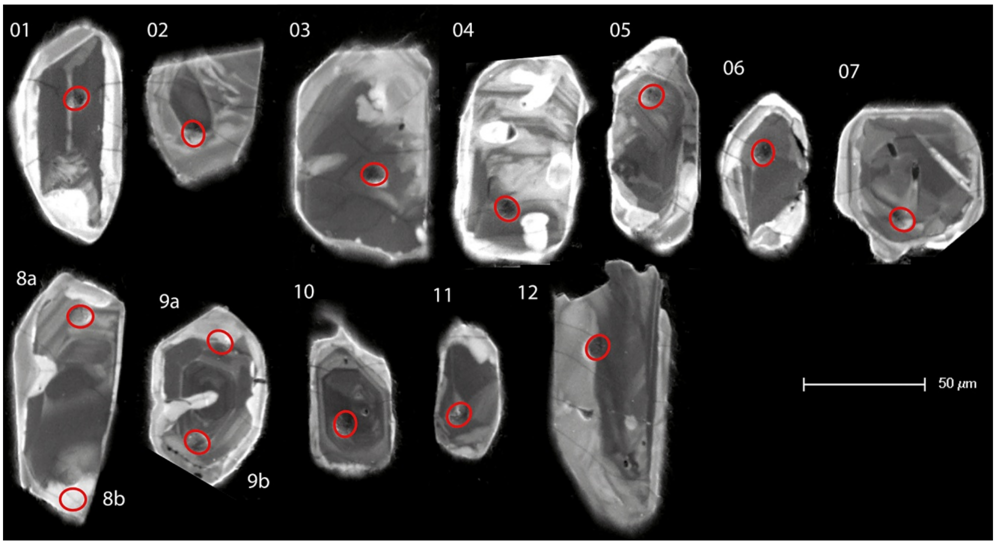

Figure 6. Cathodoluminescence (CL) images of analysed zircon grains. Numbers refer to analytical spot number in Table 2.

On the concordia diagram all 14 data points are concordant within assigned analytical error. Two analyses 8b and 12 have large errors and the latter plots at a younger age than the majority. These two analyses however, show high values of common lead (Table 2) and are discarded from the age calculations. The concordia age of the remaining 12 analyses is 1872 ±9 Ma (95% confidence, MSWD of concordance = 0.024, Probability of concordance = 0.88). The weighted average $^{207}Pb/^{206}Pb$ age of the same analyses is 1872±15 Ma (95% conf.). Point 3 has an apparent $^{207}Pb/^{206}Pb$-age of 1911±24 Ma (2σ) and the error bar does not overlap the average age. The CL-bright rims do not have statistically significant younger ages than the darker material in the interior parts and were most likely formed in a late magmatic phase. The concordia age at 1872 ±9 Ma is chosen as the best age estimate and is interpreted to date igneous crystallisation of the rhyolite.

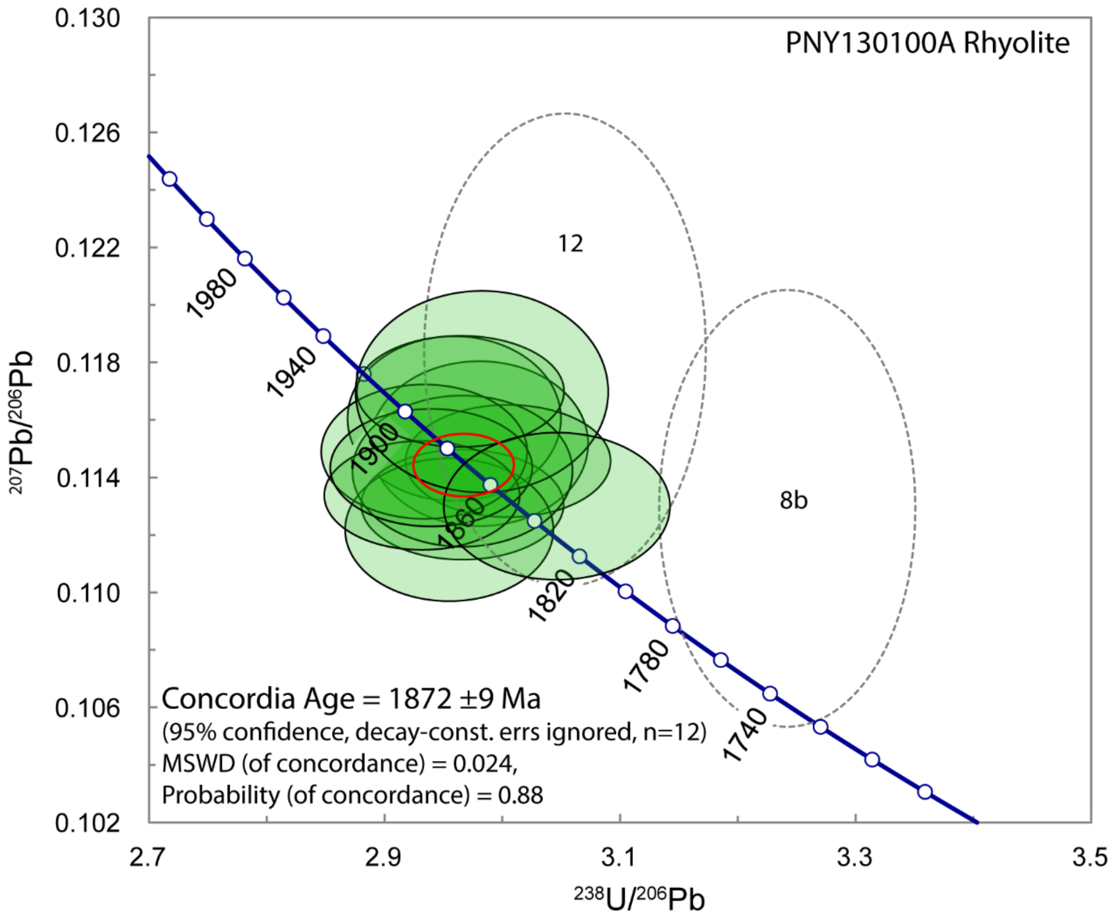

Figure 7. Tera Wasserburg diagram showing U-Pb SIMS data of zircon analyses. Two analyses (No 8b, 12) with high common lead are shown with broken lines and are excluded from age calculations. Error ellipse of calculated weighted mean age is shown in red.

Table 2. SIMS U-Pb-Th zircon data (PNY130100A, laboratory id n5399).

							Isotope ratios							Calculated ages (Ma)			
Sample/ spot #	**Spot location**	**Comment**	**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]**	**$^{207}Pb/^{206}Pb$**	**±σ**	**$^{206}Pb/^{238}U$**	**±σ**
n5399-01	core	Rounded. Wide, bright rim and dark grey interior. Both have faint, irregular zoning.	237	100	98	0.43	2.966	1.18	0.1131	0.69	9213	0.20	1.5	1849	12	1873	19
n5399-02	mixed core rim	Fragmented crystal. It has a small, dark grey core and a wide light grey mantle.	99	43	41	0.45	2.980	1.27	0.1152	1.02	9479	0.20	-1.1	1883	18	1865	21
n5399-03	core	Subhedral. Irregular, patchy zoning. The interior is dark grey and most of the outer part is light grey.	198	86	83	0.44	2.964	1.21	0.1170	0.67	54619	{0.03}	-2.2	1911	12	1874	20
n5399-04	core	Rounded. Very bright material along the rim and in rounded interior domains. The rest of the interior has both oscillatory and irregular zoning.	212	77	84	0.35	3.046	1.29	0.1130	0.92	2771	0.67	-1.2	1849	17	1830	21
n5399-05	core	Subhedral. The central part is medium grey. The peripheral parts are light grey and at some places white. Irregular zoning, at some places oscillatory.	150	44	61	0.30	2.959	1.25	0.1161	1.01	20124	0.09	-1.2	1897	18	1877	20
n5399-06	core	Subhedral-rounded. The central part is medium-dark grey and more or less homogeneous. The wide rim is light grey and white.	211	77	86	0.36	3.005	1.18	0.1146	0.70	10911	0.17	-1.3	1874	12	1852	19
n5399-07	core	Equant crystal. Light-medium grey interior with patchy zoning. Rim with light grey and white material.	160	50	65	0.30	2.955	1.22	0.1122	0.90	7040	0.27	2.7	1835	16	1879	20
n5399-08a	core	Subhedral grain. The central area is various shades of grey, partly with oscillatory, partly with irregular zoning. The rim is white or light grey.	121	34	49	0.29	2.966	1.29	0.1142	0.94	50052	{0.04}	0.3	1868	17	1873	21
n5399-08b	rim	The same crystal as 08a.	89	46	36	0.43	3.053	1.60	0.1184	2.83	997	1.88	-6.3	1933	50	1826	26
n5399-09a	core	Short, subhedral crystal. Grey, interior with faint oscillatory zoning and light grey and white rim. The bright material protrudes into the darker material.	67	38	29	0.54	2.982	1.47	0.1170	1.22	11386	{0.16}	-2.8	1911	22	1864	24
n5399-09b	mixed core rim	The same crystal as in 09a.	185	62	76	0.34	2.933	1.22	0.1149	0.83	36670	{0.05}	0.8	1879	15	1891	20
n5399-10	core	Subhedral. It has a dark grey core with euhedral shape, surrounded by a medium grey mantle also with euhedral shape. The rim is white.	291	114	121	0.38	2.932	1.16	0.1134	0.68	5562	0.34	2.3	1855	12	1892	19
n5399-11	core	Rounded crystal. Dark to medium grey interior with patchy zoning. White rim at one end.	199	68	82	0.35	2.939	1.19	0.1144	0.73	35092	{0.05}	1.1	1870	13	1888	20
n5399-12	mixed core rim	Large grain. Dark grey interior with faint, irregular zonation. Light grey, wide rim.	90	56	35	0.53	3.242	1.37	0.1129	2.75	792	2.36	-7.0	1847	49	1733	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 Pb_{com}, assuming a single stage of closed U-Th-Pb evolution

[2] % 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.

DISCUSSION AND CONCLUSION

The sampled rhyolite was named "manganporfyr" by Ödman (1947), clearly linking it to the mineralisations present at Ultevis. In this age determination, the age 1872 ± 9 Ma is interpreted as the crystallization age of the rhyolite. This is within the age interval given for the Arvidsjaur group of volcanic rocks. At the top of Hårås, 1 km north, and at Rakten, 3 km southwest of the dating locality, rich manganese mineralisations occur, forming skarn in a marble horizon close to the contact of the rhyolite to the overlying Snavva–Sjöfallet group. Especially at Rakten, along the northern shore of the lake Tjaktjajaure, excellent exposures exist showing the complete succession of rocks from rhyolite to marble followed by basaltic layers and agglomerate horizons. Further to the northwest, sandstone and arkose, locally bearing Mn-andalusite, occur in Snavva–Sjöfallet group rocks. The manganese mineralisation has been described as a volcanogenic Mn-Fe-Ba-As exhalite formation formed by exhalation from a hydrothermal vent at the interface between volcanoclastic rocks and siliceous carbonate, now transformed into skarn-bearing marble and chert-banded rock (Carlon 1984). Later partial remobilization of the syngenetically formed ore is manifested as Mn-oxides and Mn-silicates in pegmatites (Ödman 1947) probably related to 1.8 Ga intrusions of granite to the south. A uranium deposit is known from Lulep Manak, a few kilometres to the west of Hårås, where 1.8 Ga pegmatite has intruded sedimentary rocks belonging to Snavva–Sjöfallet group (Sundbergh 1979). Furthermore, locally highly radioactive Ba-Mn-oxide (hollandite) occurs in pegmatites intruding rhyolite close to the dating locality.

It is hereby proposed that the 1.87 Ga dacites and rhyolites belonging to the Arvidsjaur group may potentially host mineralisations carrying Mn, Fe, Ba, As, Mo, W, and F. Especially stratigraphically high up in the volcanic pile, close to in shallow water deposited sedimentary strata, a favorable position in which to locate mineralisations may be sought. To the south, at the border between the map areas 27I Tjåmotis NV and SV, the contacts between felsic volcanic rocks, including agglomeratic horizons, and sedimentary rocks (marble and meta-sandstone) can be traced around the 1.8 Ga Tjåmotis intrusion. The manganese mineralisation is strongly indicated by concentrations of local piemontite boulders just south of Tjåmotis. To the north of the dating locality, the contact zone continues through the 28I Stora Sjöfallet SV and SO (Zachrisson & Witschard 1995 Witschard & Zachrisson 1995) and NV (Zachrisson & Witschard, 1995) map sheets. The manganese mineralisation can be followed to Lulep Stuor Njåske ("Manganravinen") in the southern part of 28ISV and SO maps where it disappears. Banded iron formations, probably belonging to the same mineralising system, have been found by us (PN), 3 to 4 km further to the north at Juoråive (28I SO). The age obtained for the above described rhyolite also gives a maximum age of deposition for the Snavva-Sjöfall group of sedimentary rocks.

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