U-Pb zircon age of a metaquartz monzonite in the type area of the Haparanda suite

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January 2015

SGU-rapport 2015:02

Sveriges geologiska undersökning
Geological Survey of Sweden

Cover: Geologist Ulf Bergström in action during preparation of metaquartz monzonite sample STB131001A, documented by geophysicist Mehrdad Bastani at the Kurkijänkkä quarry, near Haparanda. Photo: Stefan Bergman.

Recommended reference to this report: Bergman, S., Hellström, F. & Bergström, U., 2015: U-Pb zircon age of a metaquartz monzonite in the type area of the Haparanda suite. SGU-rapport 2015:02, 13 pp.

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ABSTRACT

Metaquartz monzonite from the Haparanda suite in its type area has been dated with the U-Pb SIMS method on zircon. A concordia age has been calculated at 1884±7 Ma, and it is chosen as the best age estimate of igneous crystallisation. This quartz-poor rock has an age that overlaps with previously published ages of more quartz-rich metagranitoids in the region. This indicates that the overall compositional variation is due to different magmatic processes that were active during the same main magmatic event.

SAMMANFATTNING

Zirkon från ett prov av metakvartsmonzonit i Haparandasviten har daterats med U-Pb-SIMS-metoden. En konkordiaålder har beräknats till 1884±7 miljoner år och den bedöms vara den bästa uppskattningen av åldern för magmatisk kristallisation. Åldern för denna kvartsfattiga bergart sammanfaller med publicerade åldrar för mer kvartsrika metagranitoider i området. Detta tyder på att sammansättningsvariationerna beror på att olika magmatiska processer varit aktiva under samma magmatiska händelse.

Keywords: Radiometric age, Haparanda suite, Svecokarelian orogen, Barents project

INTRODUCTION

The purpose of this study is, firstly, to obtain a crystallisation age of a metamorphosed quartz monzonite in the type area of the Haparanda suite, and, secondly, to investigate if such quartz-poor rocks and previously studied granitoid rocks are coeval or if they could belong to different intrusive suites.

The name “Haparanda series” was originally used for a group of intrusions of granite, granodiorite, quartz diorite, diorite and gabbro in the Haparanda area (Ödman et al. 1949), and was later also used for similar rocks further north (Ödman 1957). Since then, that name and the more appropriate “Haparanda suite” have been used extensively in northernmost Sweden, and the name Haaparanta suite is in use in Finland.

Öhlander (1984) used geochemical data to suggest that the Haparanda suite is of I-type and generated in a compressional environment. Mellqvist et al. (2003) compiled geochemical and Sm-Nd isotope data and showed that the Haparanda suite has mainly negative $\varepsilon_{Nd(t)}$ values and an alkalic, calc-alkaline trend. They concluded that it was formed in a continental arc setting by fusion of Archean continental and depleted mantle material related to subduction of Proterozoic lithospheric mantle, in contrast to the coeval Jörn GI suite in the Skellefte district, which was formed in a juvenile, Paleoproterozoic volcanic-arc setting.

Modal data compiled from Ödman (1957) and Perttunen (1991) show that most rocks have a dioritoid or gabbroid composition (Fig. 1). There is a strong “quartz-poor” trend from diorite or gabbro to quartz monzonite (syenitoid trend), and possibly a second “quartz-rich” trend leading to granitoid compositions (granitoid trend). The cause of these variations is not within the scope of this report.

Results from recent mapping in the Haparanda-Kukkola-Sangis area (Fig. 2) show that the rocks are quartz-poor in the southern massif around and west of Haparanda (the type area of the Haparanda suite), while they are more quartz-rich (granitoid composition) in the northern

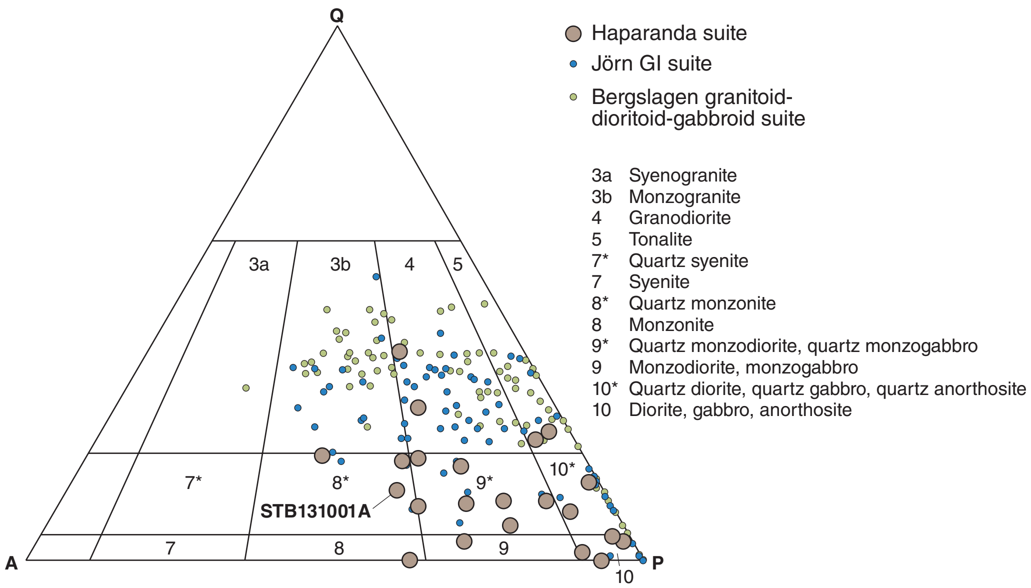

Figure 1. Modal data from the Haparanda region (Ödman 1957, Perttunen 1991) including sample STB131001A, plotted in a QAP diagram (Le Maitre 2002). Rocks from the Jörn GI suite in southern Norrbotten and northern Västerbotten counties (SGU, unpublished data) and the granitoid-dioritoid-gabbroid intrusive rock suite in the north-eastern part of the Bergslagen region (Stephens et al. 2009) are shown for comparison.

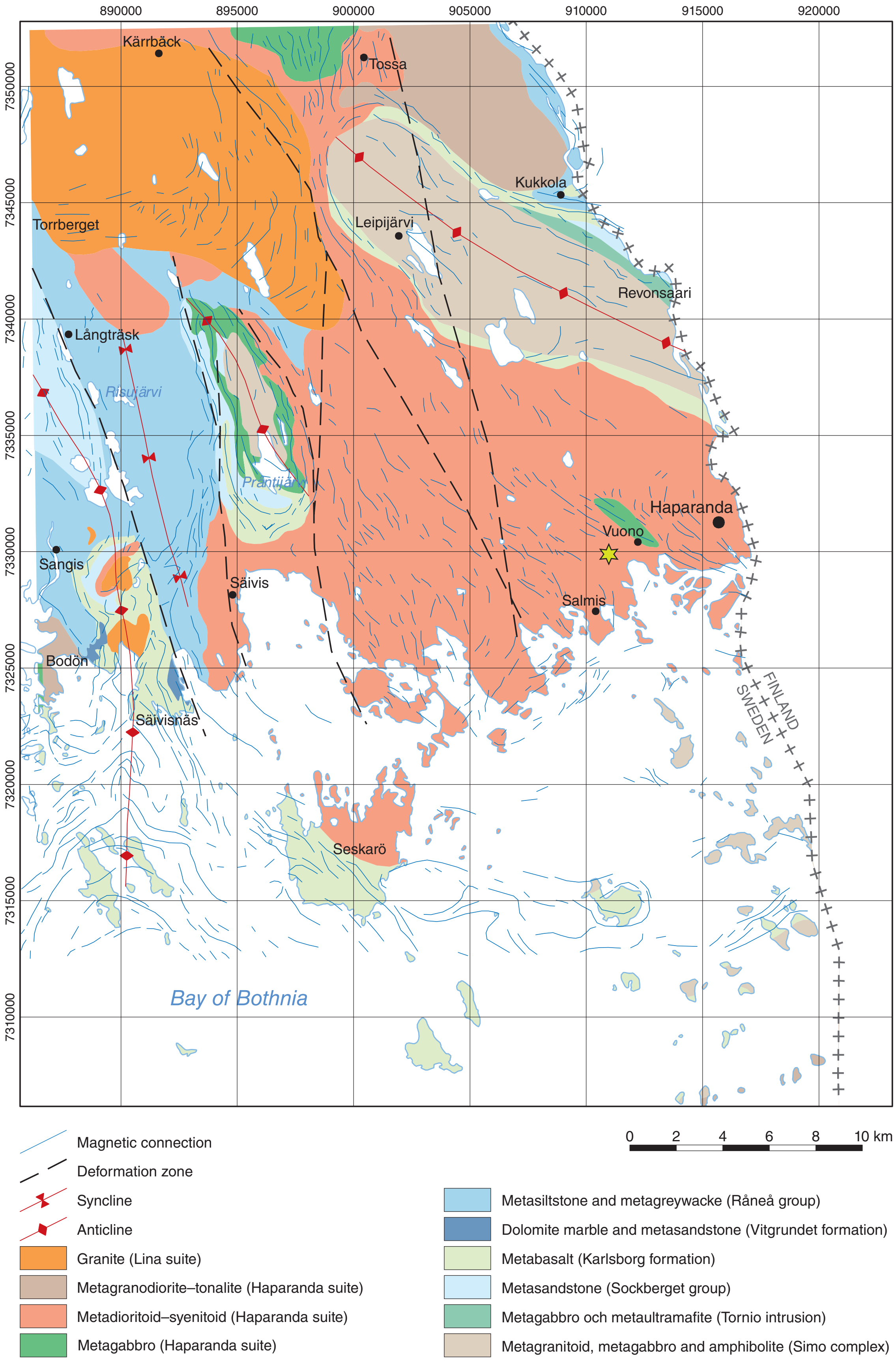

Figure 2. Preliminary bedrock map of the Haparanda-Kukkola-Sangis area. Location of the dated sample STB131001A is shown by a yellow star.

massif north-west of Kukkola. By combining the results from mapping in adjacent areas (e.g. Perttunen 1991, Wikström 1996, Åkerman & Kero 2011), the northern massif appears to be part of a granitoid belt from east of Kukkola (in Finland) to west of Kalix.

Previous U-Pb zircon age determinations in the Haparanda-Luleå region of rocks belonging to the Haparanda suite include age determinations of a granodiorite at 1883±6 Ma (Wikström & Persson 1997), a granodiorite at 1891±32 Ma (Mellqvist et al. 2003) and a tonalite at 1881±6 Ma (Åkerman & Kero 2012). They are thus all granitoids.

SAMPLE DESCRIPTION

The sample was collected from fresh material in an active quarry near Kurkijänkka, 5 km west-south-west of Haparanda town (Fig. 2, Table 1). The sample is composed of a grey, medium-grained, very weakly foliated and partly recrystallised rock classified in the field as a meta-dioritoid (Fig. 3A). According to the modal composition the sampled rock is a quartz monzonite (Fig. 1). The main minerals are hornblende (43%), plagioclase (23%), K-feldspar (15%), biotite (10%) and quartz (6%). Relic clinopyroxene is partly transformed into hornblende (Fig. 4). Accessory phases include magnetite, apatite and zircon. The sample has the chemical composition of quartz monzonite in a Q-P diagram (Debon & LeFort 1983) and syenodiorite in a total alkali vs. silica diagram (Wilson 1989). In the outcrop, mafic magmatic enclaves are ubiquitous

Table 1. Background information of dated sample.

Rock type:	Metaquartz monzonite
Tectonic domain:	Svecokarelian orogen
Tectonic subdomain:	Överkalix lithotectonic unit
Lithodemic unit:	Haparanda suite
Sample number:	STB131001A
Lab-id:	n4822
Coordinates:	7329900/910975 (SWEREF)
Map sheet:	73J SV (SWEREF), 25N Haparanda NV (RT90)
Locality:	Kurkijänkkä, 5 km west-south-west of Haparanda
Project:	Barents

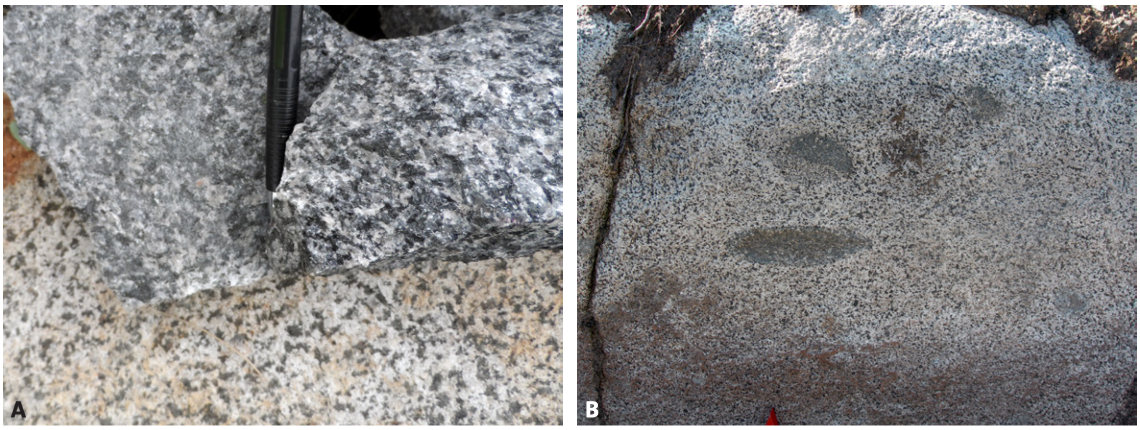

Figure 3. **A.** Photograph of the dated sample lying on the weathered outcrop surface. The pen is c. 8 mm wide. **B.** Photograph near the sampling locality of the dated metaquartz monzonite with mafic and composite magmatic enclaves. The longest dimension of the largest enclave is c. 25 cm. Photo: Stefan Bergman.

(Fig. 3B) and locally concentrated in zones resembling synplutonic dykes. Composite magmatic enclaves are locally observed. The sample was taken in a homogeneous part, devoid of enclaves.

ANALYTICAL RESULTS AND INTERPRETATION OF GEOCHRONOLOGICAL DATA

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 cathodoluminescence imaging using electron microscopy at the Swedish Museum of Natural History in Stockholm. High-spatial resolution secondary ion masspectrometer (SIMS) analysis was done in November 2013 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 lead corrected isotope values were calculated using modern common lead 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 software Isoplot 4.15 (Ludwig 2012). After the SIMS analyses, back-scattered electron (BSE) and cathodoluminescence (CL) images of analysed zircons were taken using standard electron microscopy at the Department of Geology, Uppsala University.

The heavy mineral concentrate is rich in zircon which is weakly pinkish and transparent with usually long prismatic, euhedral crystal shapes. Many grains are broken into fragments. Microcracks are common and many grains are turbid along these cracks. CL-images show weakly oscillatory zoned zircon crystals that are interpreted to be of igneous origin (Fig. 5). All nine analyses are concordant at the two sigma limit and have low values of common lead. The analyses contain 128–532 ppm U and have Th/U ratios of 0.40–0.82 (Table 2). A concordia age is calculated at 1884±7 Ma (2σ, MSWD of concordance = 1.8, probability of concordance = 0.18, n = 9, Fig. 6) and the weighted average ^{207}Pb/^{206}Pb age is 1881±8 Ma (2σ, MSWD = 0.91, probability = 0.51, n = 9), i.e. within error same as the concordia age. The concordia age at 1884±7 Ma (2σ) is chosen as the best age estimate interpreted to date igneous crystallisation of the Haparanda metaquartz monzonite at 1.88 Ga.

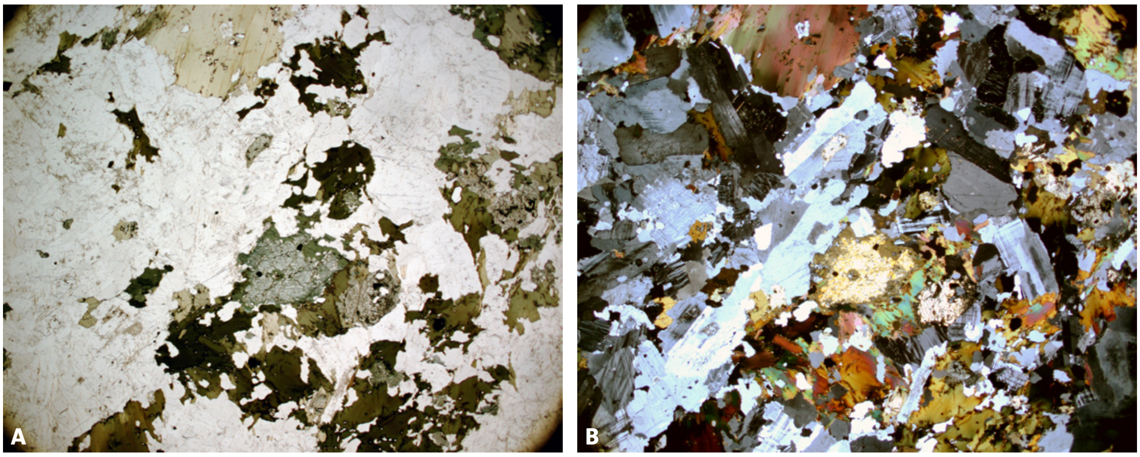

Figure 4. Photomicrographs of the dated sample. In the central part of the images relic clinopyroxene is partly transformed into hornblende. The longest dimensions of the images correspond to c. 12 mm. **A.** Plane polarized light. **B.** Crossed nicols.

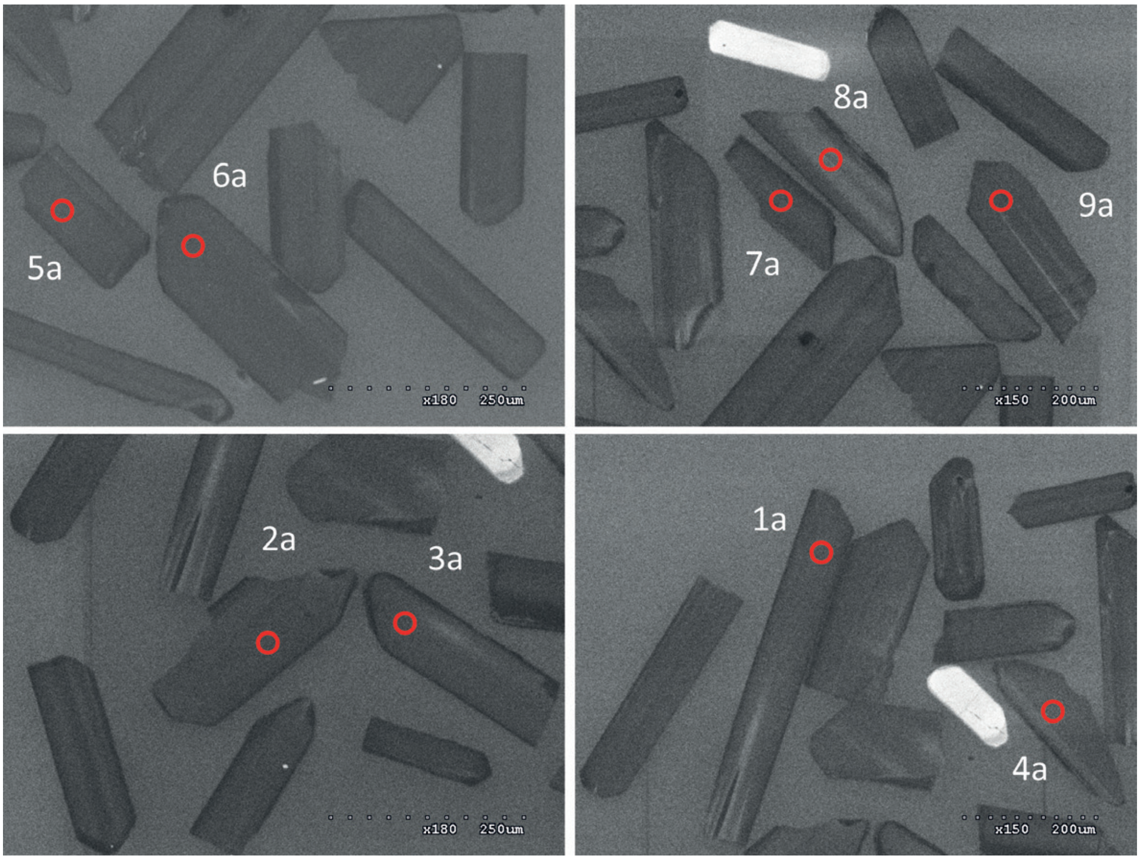

Figure 5. Cathodoluminescence images of analysed zircon grains. Red ellipses mark the approximate locations of analyses. Numbers refer to the analytical spot number in Table 1.

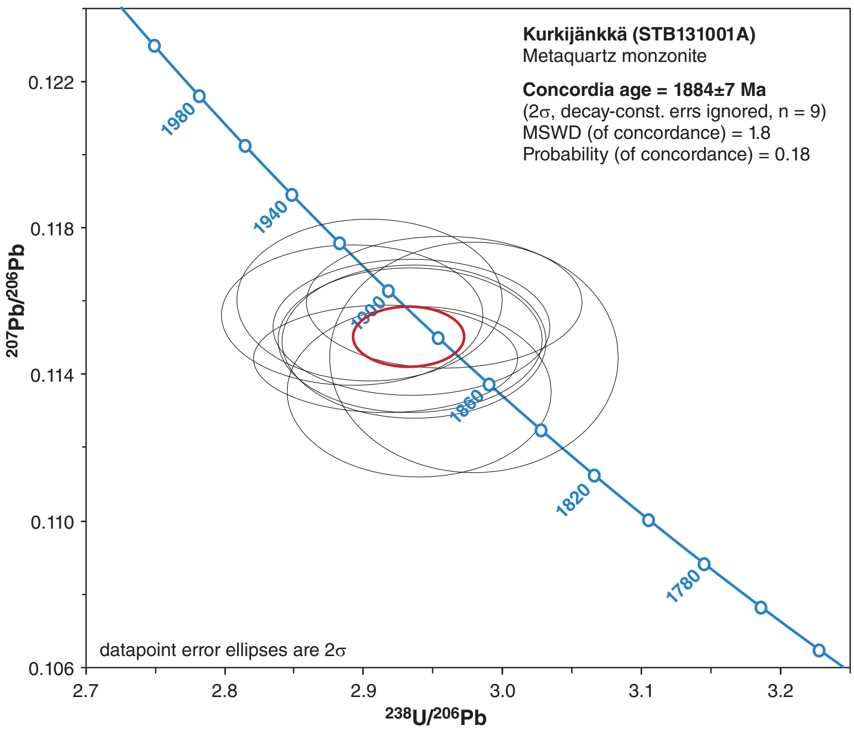

Figure 6. Tera Wasserburg diagram showing U-Pb SIMS data of zircon analyses. Error ellipse of calculated weighted mean age is shown in red.

Table 2. SIMS U-Pb-Th zircon data (STB131001A).

Analysis	Zircon texture & shape	U (ppm)	Th (ppm)	Pb (ppm)	Th/U calc.[1]	$^{207}Pb/^{235}U$	±σ (%)	$^{238}U/^{206}Pb$	±σ (%)	$^{207}Pb/^{206}Pb$	±σ (%)	ρ[2]	Disc.% conv.[3]	$^{207}Pb/^{206}Pb$ age (Ma)	±σ	$^{206}Pb/^{238}U$ age (Ma)	±σ	$^{206}Pb/^{204}Pb$ measured	f_{206}%[4]
n4822-01a	Osc zon, long	326	283	149	0.78	5.394	1.52	2.936	1.32	0.1149	0.74	0.87	0.7	1878	13	1889	22	24068	0.08
n4822-02a	Osc zon, medium	293	269	137	0.82	5.513	1.49	2.891	1.33	0.1156	0.68	0.89	1.6	1889	12	1915	22	53204	{0.04}
n4822-03a	Osc zon, long	273	247	127	0.81	5.508	1.55	2.904	1.34	0.1160	0.78	0.86	0.7	1896	14	1907	22	21147	0.09
n4822-04a	Osc zon, medium	352	321	161	0.81	5.405	1.50	2.958	1.37	0.1160	0.63	0.91	–1.1	1895	11	1877	22	46980	{0.04}
n4822-05a	Osc zon, medium	351	314	160	0.79	5.325	1.56	2.940	1.32	0.1135	0.84	0.84	1.9	1857	15	1887	22	59723	{0.03}
n4822-06a	Osc zon, long	532	465	243	0.78	5.411	1.43	2.916	1.33	0.1144	0.53	0.93	1.9	1871	9	1901	22	37334	0.05
n4822-07a	Osc zon, fragment	354	302	160	0.74	5.402	1.50	2.933	1.32	0.1149	0.70	0.88	0.7	1879	13	1891	22	12250	0.15
n4822-08a	Osc zon, long	128	59	53	0.40	5.298	1.81	2.979	1.42	0.1145	1.12	0.79	–0.4	1872	20	1866	23	10876	0.17
n4822-09a	Osc zon, long	380	337	173	0.77	5.417	1.54	2.934	1.39	0.1153	0.66	0.90	0.4	1884	12	1891	23	22253	0.08

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. Age discordance in conventional concordia space. Positive numbers are reverse discordant.
4. Figures in parentheses are given when no common lead correction has been applied, and indicate a value calculated assuming present-day Stacey-Kramers common Pb.
Osc zon = Oscillatory zoned, long = high length/width ratio , medium = medium length/width ratio.

DISCUSSION AND CONCLUSION

The results that were obtained in this study confirm that the Haparanda suite has an age of c. 1.88 Ga, in agreement with previous results from outside of the type area.

Intrusive suites in southern and central Sweden show distinct compositional trends in rock classification diagrams. In e.g. Bergslagen, rocks of the c. 1.9 Ga granitoid-dioritoid-gabbroid intrusive suite shows a clear quartz-rich granitoid trend (Fig. 1, Stephens et al. 2009) while rocks of younger suites show trends with lower quartz contents, e.g. syenitoid trends. The same general features are also found in the southern Norrbotten and northern Västerbotten counties (Fig. 1), where granitoids of the Jörn GI suite preceeded, with an overlap in time, the more quartz-poor rocks of the Perthite monzonite suite (Kathol & Weihed 2005). The fact that the analysed quartz-poor rock at Kurkijänkkä has an age that is comparable with previously published ages of more quartz-rich metagranitoids in the region indicates that the overall compositional variation is due to different magmatic processes that were active during the same main magmatic event.

ACKNOWLEDGMENTS

U-Pb isotopic zircon data were obtained from the beneficial co-operation with the Laboratory of Isotope Geology at the Swedish Museum of Natural History in Stockholm. Martin Whitehouse, Lev Ilyinsky and Kerstin Lindén at the Nordsim analytical facility are gratefully acknowledged for their excellent analytical support with SIMS-analyses. Martin Whitehouse performed the U-Pb data reduction. Jarek Majka at the Department of Geology, Uppsala University, is much thanked for his support during BSE/CL-imaging of zircons.

REFERENCES

Åkerman, C. & Kero, L., 2011: Bedrock map 26N Karungi SV, scale: 1:50 000. *Sveriges geologiska undersökning K 399*.

Åkerman, C. & Kero, L., 2012: Bedrock map 26M Överkalix SO, scale:1:50 000. *Sveriges geologiska undersökning K 398*.

Debon, F. & Le Fort, P., 1983: A chemical-mineralogical classification of common plutonic rocks and associations. *Transactions of Royal Society of Edinburgh, Earth Sciences 73*, 135–149.

Kathol B. & Weihed P., (Eds.) 2005: Description of regional geological and geophysical maps of the Skellefte District and surrounding areas. *Sveriges geologiska undersökning Ba 57*, 197 pp.

Le Maitre, R.W. (Ed.), 2002: *Igneous rocks. A classification and glossary of terms*. 2nd edition. Recommendations of the International Union of Geological Sciences Subcommision on the Systematics of Igneous Rocks. Cambridge University Press, 236 pp.

Ludwig, K.R., 2012: User's manual for Isoplot 3.75. A Geochronological Toolkit for Microsoft Excel. Berkeley *Geochronology Center Special Publication No. 5*, 75 pp.

Mellqvist, C., Öhlander, B., Weihed, P. & Schöberg, H., 2003: Some aspects on the subdivision of the Haparanda and Jörn intrusive suites in northern Sweden. *GFF 125*, 77–85.

Ödman, O.H., 1957: Beskrivning till berggrundskarta över urberget i Norrbottens län. *Sveriges geologiska undersökning Ca 41*, 151 pp.

Ödman, O.H., Härme, M., Mikkola, A. & Simonen, A., 1949: Den svensk-finska geologiska exkursionen i Tornedalen sommaren 1948. *Geologiska Föreningens i Stockholm Förhandlingar 71*, 113–126.

Öhlander, B., 1984: Geochemical analyses of rocks of the Haparanda suite, northern Sweden. *Geologiska Föreningens i Stockholm Förhandlingar 106*, 167–169.

Perttunen, V., 1991: Kemin, Karungin, Simon ja Runkausen kartta-alueiden kallioperä. Summary: Pre-Quaternary rocks of the Kemi, Karunki, Simo and Runkaus map-sheet areas.

Geological map of Finland 1:100 000. Explanation to the maps of Pre-Quaternary rocks, sheets 2541 Kemi, 2542 + 2524 Karunki, 2543 Simo and 2544, 1–80.

Stacey, J.S. & Kramers, J.D., 1975: Approximation of terrestrial lead isotope evolution by a two-stage model. *Earth and Planetary Science Letters 26*, 207–221.

Steiger, R.H. & Jäger, E., 1977: Convention on the use of decay constants in geo- and cosmochronology. *Earth and Planetary Science Letters 36*, 359–362.

Stephens, M.B., Ripa, M., Lundström, I., Persson, L., Bergman, T., Ahl., M., Wahlgren, C.-H., Persson, P.-O. & Wickström, L., 2009: Synthesis of the bedrock geology in the Bergslagen region, Fennoscandian Shield, south-central Sweden. *Sveriges geologiska undersökning Ba 58*, 259 pp.

Whitehouse, M.J., Claesson, S., Sunde, T. & Vestin, J., 1997: Ion-microprobe U–Pb zircon geochronology and correlation of Archaean gneisses from the Lewisian Complex of Gruinard Bay, north-west Scotland. *Geochimica et Cosmochimica Acta 61*, 4429–4438.

Whitehouse, M.J., Kamber, B.S. & Moorbath, S., 1999: Age significance of U–Th–Pb zircon data from Early Archaean rocks of west Greenland: a reassessment based on combined ion-microprobe and imaging studies. *Chemical Geology (Isotope Geoscience Section) 160*, 201–224.

Wiedenbeck, M., Allé, P., Corfu, F., Griffin, W.L., Meier, M., Oberli, F., von Quadt, A., Roddick, J.C. & Spiegel, W., 1995: Three natural zircon standards for U–Th–Pb, Lu–Hf, trace element and REE analysis. *Geostandards Newsletter 19*, 1–23.

Wiedenbeck, M., Hanchar, J., Peck, W.H., Sylvester, P., Valley, J., Whitehouse, M., Kronz, A., Morishita, Y., Nasdala, L., Fiebig, J., Franchi, I, Girard, J.-P., Greenwood, R.C., Hinton, R., Kita, N., Mason, P.R.D., Norman, M., Ogasawara, M., Piccoli, P.M., Rhede, D., Satoh, H., Schulz-Dobrick, B., Skår, Ø., Spicuzza, M.J., Terada, K., Tindle, A., Togashi, S., Vennemann, T., Xie, Q. & Zheng Y.-F., 2004: Further characterization of the 91500 zircon crystal. *Geostandards and Geoanalytical Research 28*, 9–39.

Wikström, A., 1996: Berggrundskartan Kalix NO. *Sveriges geologiska undersökning Ai 80*.

Wikström, A. & Persson, P.-O., 1997: U-Pb zircon and monazite dating of a Lina type leucogranite in northern Sweden and its relationship to the Bothnian shear zone. *In* T. Lundqvist (Ed.): Radiometric dating results 3. *Sveriges geologiska undersökning C 830*, 81–87.

Wilson, M., 1989: *Igneous petrogenesis: A global tectonic approach*. London, Unwin. Hyman, 466 pp.