U-Pb zircon geochronology of granitic and syenitoid rocks across the southern part of the Sveconorwegian orogen

Jenny Andersson (Editor)

SGU-rapport 2012:14
Cover: Photo in optical microscope of polished mount with zircon from a meta-granite at Vättnet, Nordkoster. Image taken prior to U-Pb LA-SF-ICP-MS analysis.
EDITOR’S PREFACE

Geochronology is a fundamental cornerstone in bedrock mapping. In the Precambrian, the absence of a useful fossil record requires application of radiometric dating methods. The radiometric ages are a prerequisite for understanding how the bedrock is constructed and how rocks are related in space and time. Radiometric age determinations are therefore an integral part of the bedrock mapping programme of the Geological Survey of Sweden. The geochronological data are published as short notes in the report series “SGU-rapporter”.

This publication presents U-Pb zircon data from across the eastern part of the Sveconorwegian orogen (as outlined by e.g. Berthelsen 1980 and Bingen et al. 2008, see Fig. 1). The large scale tectonic reconfiguration of crustal scale bedrock units, and the in part deep subduction of crust, has had a fundamental bearing on the character of the bedrock in this part of the shield area. It thus directly governs the usability of rocks for societal applications. The first report by Eliasson et al. (a) presents data from the upper tectonic levels of the Sveconorwegian orogen that forms a boundary between deeply subducted high-grade metamorphic rocks in the west and well preserved igneous rocks in the pre-Sveconorwegian foreland in the east (Fig. 1). The results show that the rocks in the Tokeryd area, north-north-west of Jönköping, are related to strongly metamorphosed and deformed gneissic rocks in the lower tectonic levels of the Sveconorwegian orogen in the west. The second paper by Lundqvist et al. presents time constrains on igneous crystallisation of protoliths to strongly reworked, veined gneisses in the Eastern Segment in the Alingsås area. The results show that the protoliths to the high-grade metamorphic rocks in the western, deeply subducted, lower tectonic levels of the Eastern Segment are linked to well preserved rocks in the upper tectonic levels in the east. It confirms a link with the well preserved intrusion at Tokeryd, described by Eliasson et al. (a) in paper I, and thus corroborates the parautochthonous nature of the Eastern Segment. The data also help to constrain the outline of the lithotectonic boundary to the overlying allochthonous Idefjorden Terrane for which the link to the pre-Sveconorwegian rocks in the foreland region is unclear. In paper III, Eliasson et al. (b) present data on a structurally young granite intrusion at Nordkoster in the south-western parts of the Idefjorden Terrane. The new data demonstrate a clear
link to Gothian orogenesis and overrule a younger Mesoproterozoic affinity. The data also set an upper age constraint for the voluminous mafic dyke swarm of unknown age (Koster dyke swarm of Hageskov 1985) that intrudes the dated granite.

The data in papers one and three were obtained in collaboration between SGU and GEUS (Geological Survey of Denmark and Greenland). This work was made possible by the kind and skillful co-operation of Dirk Frei (former senior advisor at the ICPMS laboratory, Ministry of Climate and Energy, GEUS, Copenhagen) which is gratefully acknowledged. Data in paper two were obtained from beneficial co-operation with the Laboratory for Isotope Geology of the Swedish Museum of Natural History in Stockholm, and the head of NORDSIM, Dr. Martin Whitehouse, and his staff are greatly acknowledged for first class analytical support.

Uppsala, 26th of June 2012
Jenny Andersson

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U-Pb ZIRCON AGE OF A TIB-2 QUARTZ MONZONITE FROM TOKERYD IN THE PROTOGINE ZONE NORTH-WEST OF JÖNKÖPING, SOUTH CENTRAL SWEDEN

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Aim of study

The easternmost part of the Sveconorwegian orogen is dominated by rocks belonging to the Transscandinavian Igneous Belt (TIB, Högdahl et al. 2004). The TIB consists of large batholiths composed of granite–syenitoid–dioritoid–gabbroid rocks and associated volcanic equivalents. Ages range between 1.85 and 1.65 Ga (Högdahl et al. 2004 and references therein) and show an overall southward to south-westward younging trend. The TIB has been divided into three age groups: TIB-1 at 1.81–1.76 Ga, TIB-2 at 1.71–1.68 Ga and TIB-3 at 1.67–1.65 Ga (Larson & Berglund 1992). In the Jönköping area, TIB-1 rocks principally occur in the eastern part whereas the south-western and western areas principally expose TIB-2 rocks (e.g. Wik et al. 2006, Eliasson et al. 2008, Appelquist et al. 2009).

This study presents U-Pb data for zircon from a quartz monzonite that is exposed as several small bodies situated some 15 km north-north-west of Jönköping (Larson & Berglund 1995). The adjacent rocks to the east are dark grey, microcline porphyritic granite to quartz monzodiorite belonging to TIB-1. TIB-2 rocks, mainly microcline porphyritic granites (Barnarp type) with small intrusions of reddish, equigranular TIB-2 granites, occur farther to the west and south. The majority of these rocks are fairly well preserved igneous rocks. Deformation increases towards the south-west and a gneissosity becomes visible in the TIB-2 granites. Strong ductile deformation is mainly restricted to the contact zone between the TIB-1 and TIB-2 units and it is interpreted to predate the north–south trending steep to sub-vertical discrete deformation zones characteristic for deformation in the Protogine Zone (Wik et al. 2006).

The aim of this study is to date the igneous crystallisation of quartz monzonite bodies along the stipulated contact zone between TIB-1 and TIB-2 intrusions in the Jönköping area to constrain the western extension of TIB-1 rocks.

Sample description

The dated quartz monzonite is reddish grey, coarsely medium-grained, isotropic to weakly foliated and non-equigranular to porphyritic with less than 15 mm large microcline ± plagioclase phenocrysts (Fig. 1). In addition to the felsic minerals the rock contains biotite (c. 12 vol%), hornblende...
(c. 1 vol%), titanite (c. 1 vol%), almost 1 vol% opaque minerals, principally magnetite and ilmenite, and subordinately some pyrite. Apatite, epidote and zircon are accessory phases. In thin section, zircon occurs as small (<170 µm) tabular crystals.

Plagioclase is generally severely altered to sericite and saussurite (Fig. 2). Secondary biotite occurs as mantles on hornblende and along microfractures and grain boundaries (Fig. 2).

**U-Pb zircon analyses**

Zircon was extracted from a c. 0.5 kg large sample of reddish-grey, almost isotropic quartz monzonite. The analytical procedures are described in the Appendix. The sample was rich in zircon and the grains are overall euhedral with sharp external terminations typical for pristine crystals not exposed to secondary alteration (Fig. 3). The zircons are short to sometimes long prismatic,
typically about 50–200 µm in size, colourless and translucent and quite commonly with a greyish cloudiness. Cracks and inclusions are sparse and turbid cores are, as a rule, absent.

In cathodoluminescence (CL) images, the zircons are oscillatory zoned (Fig. 4). The zonation continues throughout the whole crystal and secondary alteration features are subordinate.
Table 1. LA-SF-ICP MS U-Th-Pb zircon data from a quartz monzonite at Tokeryd, north-north-west of Jönköping (sample TEN062005). Analyses TEN-49 and TEN-66 were excluded from age calculation.

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* All analysed domains are oscillatory zoned.

Results

Eighteen spot analyses were set in oscillatory zoned, euhedral, clear and translucent crystals without visible inclusions. Uranium contents and Th/U ratios of the analysed zircons are in the range 43–239 ppm and 0.63–1.42, respectively. Sixteen out of the eighteen analysed spots were used for age calculation. Two analyses were discarded from the age calculation: one analysis (TEN-49) had a too low count rate and one spot (TEN-66) burned through the crystal. Most of the remaining sixteen analyses plot concordantly at about 1700 Ma, but a slight horizontal spread of the cluster prohibits calculation of a common concordia age (Fig. 5). Together, however, the 16 spot analyses yield a well defined $^{206}\text{Pb}/^{207}\text{Pb}$ age of 1700±8 Ma (MSWD = 0.52, Fig. 6). This age is interpreted to date igneous crystallisation of zircon in the quartz monzonite.
Discussion and conclusion

The igneous crystallisation age of 1700±8 Ma shows that the quartz monzonitic bodies in the Bankeryd area, north-west of Jönköping, intruded more or less coevally with the adjacent Barnarp-type TIB-2 granite (Gorbatschev & Bogdanova 2006) and more strongly metamorphosed 1.7 Ga old granites and syenitoids of TIB-2 and orthogneisses farther to the west (Brander et al. 2011).

References

U-Pb IGNEOUS PROTOTLITH ZIRCON AGE OF A GRANITIC MIGMATITIC GNEISS IN THE EASTERN SEGMENT OF THE SVECONORWEGIAN OROGEN, ALINGSÅS AREA

Lena Lundqvist, Jenny Andersson & Fredrik Hellström


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Introduction

The eastern part of the Sveconorwegian orogen consists of two crustal-scale orogenic segments: (I) the parautochthonous to allochthonous Eastern Segment, adjoining the pre-Sveconorwegian foreland in the east, and (II) the allochthonous Idefjorden Terrane overlying the Eastern Segment in the west (Fig. 1). The lithotectonic boundary between the Eastern Segment and the Idefjorden Terrane is located within a west-dipping to sub-vertical, major ductile shear belt referred to as the Mylonite Zone (Stephens et al. 1996, Viola et al. 2011). These two orogenic segments show fundamentally different igneous, structural and metamorphic evolutions in both Sveconorwegian and pre-Sveconorwegian time (Bingen et al. 2008).

During the years 2003–2005, SGU conducted bedrock mapping at the scale 1:50 000 along and east of the southern shallowly west-dipping section of the Mylonite Zone, in the area of Alingsås.
Immediately west-south-west thereof, around Lake Mjörn, the Mylonite Zone has previously been outlined as a complex, shallowly west-dipping, up to 5 km wide deformation zone network that forms a major regional scale tectonic contact between Sveconorwegian tectonic sub-provinces (Park et al. 1991). During mapping carried out by SGU...
in the area of Lake Anten, lithologies on both sides of the Mylonite Zone deformation belt were identified as high-grade orthogneisses intercalated with meta-basic rocks, and the terrane affinity of the high-grade gneisses in the Alingsás area was put in question.

According to the available geochronological data, orthogneisses in the Eastern Segment have 1.74–1.65 Ga old igneous protoliths of principally granitic to syenitoid compositions (Lindh & Gorbatschev 1984, Wik et al. 2006, 2009). In contrast, orthogneiss protoliths in the Idefjorden Terrane are mainly 1.64–1.52 Ga granitoid intrusions (Åhäll & Connelly 2008). In order to test the validity of the location of the eastern boundary of the Idefjorden Terrane in the Lake Anten area (e.g. Berthelsen 1980, Park et al. 1991), a banded, migmatitic orthogneiss with a shallow dip to the north was sampled just north of the town of Alingsás for direct dating of the igneous protolith zircon. The data on the igneous protolith zircon would corroborate terrane affinity of the investigated high-grade gneiss complex.

Sample description

The sampled rock is a greyish red, compositionally banded migmatitic granitic gneiss with less than 25 vol% coarse-grained vein material. Concordant intercalations of decimeter to meter wide semi-continuous amphibolitic bands are common in this gneiss unit (Fig. 3). These bands may be remnants of mafic dyke injections or mafic enclaves. At microscale, the rock is unequigranular with irregular cusps and lobes grain-boundaries. It is a microcline-bearing leucogranitic rock with trace amounts of muscovite and less than 5 vol% mafic minerals, dominated by brown to dark beige biotite (Fig. 4A). About 50 vol% of the plagioclase is altered. Accessory phases are opaque

Figure 3. Sample locality for the dated granitic gneiss (sample FRJ031048A). Photo: Ildikó Antal Lundin, SGU.
minerals, zircon and apatite. The mineralogy of the rock indicates significant retrogression at lower grade metamorphic conditions.

**Analytical results and interpretation of geochronological data**

Analytical procedures are described in the Appendix. U-Pb-Th SIMS analysis of zircon was performed at the NORDSIM facility at the Museum of Natural History in December 2004. The
analytical results are shown in Table 1. The zircon grains in the sample are subhedral to anhedral with oscillatory zoned cores. Cathodoluminescence (CL) images show that the zoned cores are surrounded by texturally younger unzoned and irregularly shaped CL-bright domains and thin, outer CL-dark rims (Fig. 5).

Nine analyses were aimed at oscillatory zoned core domains and two analyses at CL-bright domains. The uranium content of the zircon is 111−716 ppm. Th/U ratios are 0.37−0.94 for core analyses and 0.04−0.09 for the two rim analyses (n1639-01a, n1639-02a), which also have high values of common lead (Table 1). Four of the analyses aimed at core domains are concordant and these points give a concordia age of 1666±23 Ma (95% confidence, MSWD of concordance and equivalence = 2.3, Fig. 6). The weighted average $^{207}$Pb/$^{206}$Pb age is 1670±31 Ma (95% confidence, MSWD = 1.8, probability = 0.15). The concordia age is chosen as the best age estimate suggesting igneous crystallisation of the Kvarnbacken gneiss protolith at c. 1.67 Ga.

Discussion and conclusion

Igneous crystallisation of zircon from a granitic orthogneiss at Kvarnbacken, Alingsås, was dated at 1666±23 Ma. This age is identical to igneous crystallisation of zircon in orthogneisses across
the Eastern Segment of the Sveconorwegian orogen (see age compilation in Bingen & Solli 2009). This confirms earlier interpretations suggesting that the location of the lithotectonic boundary between the Eastern Segment and the Idefjorden Terrane of the Sveconorwegian orogen is to be found within the north–south trending, shallowly west-dipping high-strain deformation belt in current literature referred to as the Mylonite Zone (cf. Berthelsen 1980, Park et al. 1991, Stephens et al. 1996, Viola et al. 2011).

Acknowledgment

Martin Whitehouse, Lev Ilyinsky and Kerstin Lindén at the Nordsim analytical facility are thanked for their assistance with SIMS-analyses.

References


U-Pb ZIRCON AGE OF THE LATE GOTHIAN VÄTTNET GRANITE ON NORD-KOSTER
IN THE IDEFJORDEN TERRANE, SOUTH-WESTERN SWEDEN

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</table>

Aim of study

The Vättnet granite is exposed in the north-eastern part of the Koster archipelago. It belongs to a granitic suite that is intrusive into the migmatitic supracrustal rocks of the Stora Le-Marstrand group (SLM, Eliasson 2011). The suite comprises two textural and compositional varieties: grey, porphyritic biotite ± hornblende granite and, subordinately, a fine- to medium-grained leucogranite. The latter varies in colour from grey to red and occurs as sheets and elongated somewhat irregular intrusions within the grey porphyritic Vättnet granite.

The Vättnet granite contains xenoliths of the migmatitic SLM meta-greywacke (Fig. 1) as well as of the adjacent Gothian meta-granodiorite to meta-tonalite intrusion. Based on detailed structural studies, Hageskov (1985) concluded that the “sheeted granite” (denoted the Vättnet granite by Eliasson 2011 and in this study) is the youngest granitic intrusion in the Koster archipelago as it show no signs of deformation prior to the Sveconorwegian shearing that affected the north-eastern part of the archipelago.
The aim of the present study is to date the igneous crystallisation of the Vättnet granite and thus the cessation of magmatism in the Koster archipelago. Metamorphosed and deformed dolerite dykes are abundant in the granite (Koster dykes, Hageskov 1985). Thus, the age of the granite will provide important information on the maximum age of the Koster dykes.

**Regional geology**

The Koster islands are located in the westernmost part of the Østfold-Marstrand belt in the Østfold-fjorden Terrane of the Sveconorwegian orogen (Berthelsen 1980, Bingen et al. 2008). The oldest lithological unit in the Koster archipelago is a meta-greywacke with minor intercalations of mafic meta-volcanic rocks of the SLM group. During the Gothian orogeny, approximately 1545 and 1520 Ma ago (Åhäll & Connelly 2008), the pervasively migmatitic SLM meta-greywacke was intruded by a number of plutonic rocks ranging in composition from gabbro to granite. The plutonic rocks were subsequently deformed and metamorphosed during the final stage of the Gothian orogeny. The dense tholeiitic Koster dyke swarm intruded in post-Gothian time as indicated by the obtained Rb-Sr age of 1421±25 Ma (Hageskov & Pedersen 1988). These dykes have been correlated with the Kattsund dyke swarm in the Sandbukta-Mølen area within Oslofjorden (Hageskov 1985) and with the 1457±6 Ma Orust dykes some 85 km to the south (Daly et al. 1983, Åhäll & Connelly 1998).

The bedrock in the north-eastern part of the Koster archipelago was intensely deformed and metamorphosed during the Sveconorwegian orogeny at 1150 to 900 Ma. The south-western part of the Koster archipelago, however, escaped much of this reworking and thus exposes a unique window into the pre-Sveconorwegian history of south-western Fennoscandia where the Gothian orogenic evolution can be studied.

**Sample description**

The dated sample of Vättnet granite is a grey, porphyritic, lineated and weakly gneissic biotite ± hornblende granite. The sample was selected in blasted outcrops from a construction site at Vättnet at the north-eastern part of Nord-Koster Island. The pronounced lineation is mainly defined by elongated clusters of biotite ± hornblende and by the preferred orientation of elongated microcline and plagioclase porphyroclasts (Figs. 2 & 3).

In more strained zones, porphyroclasts or augen consist of 4 to 10 mm large plagioclase and microcline crystals in a fine-grained to finely medium-grained matrix principally composed of more or less recrystallised quartz, plagioclase and K-feldspar with some biotite and hornblende (Fig. 4). Highly strained plagioclase porphyroclasts are recrystallised to multicrystalline grains. The granite has a relatively high content of mafic minerals. Biotite predominates (c. 13.5 vol%) over amphibole (1.1 vol%) and some 20 percent of the biotite is altered to chlorite. Microcline is commonly fresh and unaltered, whereas plagioclase is severely clouded by sericite and a very fine-grained albite + epidote + calcite saussurite assemblage (Fig. 4). Accessory pyrite is the only opaque mineral found in the dated granite.

Zircon occurs as 0.01 to 0.25 mm long euhedral grains essentially found in the aggregates of biotite ± hornblende. Garnet (c. 0.7 vol%) commonly occurs in clusters of mafic minerals.

**U-Pb zircon analyses**

Zircon was extracted from a c. 0.5 kg large sample of the Vättnet granite. The analytical procedures are described in the Appendix. The sample was rich in zircon and the crystals were of high
Figure 2. The dated Vättnet granite from Nord-Koster (TEN085058B). The L-fabric is seen parallel (A) and perpendicular (B) to the stretching direction. Length of sample c. 10.5 cm.

Figure 3. A rock surface oriented roughly parallel to the stretching lineation of the porphyritic Vättnet granite some 30 m west of the sampling locality.

Figure 4. Photomicrograph in plane-polarised (A) and crossed-polarised (B) light of the dated porphyritic and lineated Vättnet granite. In the lower right part of the photographs are two grains of garnet (grt). The thin section is cut perpendicular to the L-fabric.
analytical quality (Fig. 5). The zircons are short to long prismatic and mostly euhedral with sharp crystal terminations that appear unaffected by secondary abrasion. They are typically colourless, translucent and clear. Cracks and inclusions are sometimes present but indications of complex core-rim relations are lacking.

In cathodoluminescence (CL) images, the crystals show oscillatory zonation that vary from narrow and thinly laminated to wide broad banded domains (Fig. 6). The oscillatory zonation typically continues all the way to the crystal margin and complex core-rim zonations are not recorded. Some grains show signs of convoluted zonation.

Results

Twenty analyses were obtained from twenty different crystals. The location of analytical spots is shown in Figure 5. Analytical data is given in Table 1. The analysed zircon is somewhat low in uranium, between 39 and 197 ppm, and have Th/U ratios between 0.33 and 0.67. The twenty
analyses cluster on or close to the concordia, but are not equivalent enough to define a common concordia age. Together the twenty analyses define a 206Pb/207Pb age of 1519±9 Ma (MSWD = 0.51, 95% conf., Figs. 7 & 8).

The euhedral character of the crystals and the overall undisturbed, pervasive internal oscillatory zonation pattern of the analysed zircon sample suggest that post-igneous disturbance of the zircon system was negligible. The obtained 206Pb/207Pb age of 1519±9 Ma for the oscillatory zoned euhedral zircon population is interpreted to date the igneous crystallisation of the Vättnet granite.

The zircon population in the granite records no inheritance of the side rock or protolith rock. This suggests that the granite magma was highly aggressive to protolith zircon or that the zircon bearing wall rocks are not a contributing source to the granite magma.

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* All analysed domains are oscillatory zoned.
Discussion and conclusion

Hageskov & Mørch (2000) classified the Vättnet granite as an anorogenic intrusion. The 1519±9 Ma age for igneous crystallisation of the Vättnet granite shows that it intruded during the final stage of the Gothian orogeny. Thus, the Vättnet granite is basically synchronous with the youngest Gothian intrusions in the Idefjorden Terrane of the Sveconorwegian orogen, i.e. the 1522±10 Ma Stenungsund granodiorite in the Hisingen suite (Åhäll & Connelly 2008).

The present study proves that the granite intruded at least 60 Ma before the intrusion of the Koster dykes. The latter formed when the Gothian crust was stabilised and responded in a brittle manner to crustal extension.

References


Zircon mineral separates were obtained by density separation of about 0.5 kg of rock sample ground to a fine powder using a swing mill and then loaded on a Wilfley water table. The magnetic minerals were removed from the heavy residue by hand magnet. Zircons were hand-picked under a stereomicroscope and about 100–200 crystals from each sample were mounted on double-faced tape. The 1065 Ma Geostandards zircon 91500 (Wiedenbeck et al. 1995) was added to the mount used for ion microprobe SIMS analysis. The mounts were cast in transparent epoxy resin and well after hardening polished to expose the central parts of the crystals. Cathodoluminescence imaging was performed on polished, gold-coated mounts using a Gatan CL3 detector on a Hitachi S-4300 electron microscope at the Swedish Museum of Natural History and a Philips X30 FEH scanning electron microscope at Stockholm University.

**LA-SF-ICP-MS analyses**

Zircon ages were obtained using a laser-ablation sector field inductively coupled plasma mass spectrometer (LA-SF-ICP-MS) at the Department of Geological Mapping, Geological Survey of Denmark and Greenland (GEUS). The laser ablation microprobe uses a focused laser beam to ablate a small amount of a sample contained in an air-tight sample cell. Detailed analytical protocols are described by Gerdes & Zeh (2009) and Frei & Gerdes (2009), but a brief summary is given here.

Samples and standards were mounted in a low-volume ablation cell specially developed for U-Pb-dating (Horstwood et al. 2003). Helium was used to flush the sample cell and was mixed downstream with the argon sample gas of the mass-spectrometer. A NewWave Research®/Merchantek® UP213 laser ablation unit was used that emits a beam wavelength of 213 nm and a 10 Hz repetition rate. For the spot diameter (20 µm) and ablation times (30 s) used here, the ablated mass of zircon was typically between 150 and 300 ng. The ablated material was transferred to the mass-spectrometer in an Ar-He carrier gas via Tygon® tubing into an Element2 (ThermoFinnigan®, Bremen) single-collector double focusing magnetic sector ICP-MS. The total acquisition time for each analysis was 60 s of which the first 30 s were used to determine the gas blank.

The instrument was tuned to give large, stable signals for the $^{206}$Pb and $^{238}$U peaks, low background count rates (typically around 150 counts per second for $^{207}$Pb) and low oxide production rates ($^{238}$U/$^{238}$O generally below 2.5%). $^{202}$Hg, $^{204}$(Pb + Hg), $^{206}$Pb, $^{207}$Pb, $^{208}$Pb, $^{232}$Th and $^{238}$U intensities were determined through peak jumping using electrostatic scanning in low resolution mode and with the magnet resting at $^{202}$Hg. Each peak was determined at four slightly different masses and integrated sampling and a settling time of 1 ms for each isotope. Mass $^{202}$Hg was measured to monitor the $^{204}$Hg interference on $^{204}$Pb where the $^{202}$Hg/$^{204}$Hg $\equiv 4.36$, which can be used to correct significant common lead contributions using the model by Stacey & Kramers (1975). $^{207}$Pb/$^{235}$U was calculated from the $^{207}$Pb/$^{206}$Pb and $^{206}$Pb/$^{238}$U assuming $^{238}$U/$^{235}$U $\equiv 137.88$.

The laser induced elemental fractionation and the instrumental mass bias on measured isotopic ratios were corrected through standard-sample bracketing using the GJ-1 zircon (Jackson et al. 2004). Samples were analysed in sequences where three standards bracket each set of ten samples. The Plesovice zircon standard (Aftalion et al. 1989) has been used as an external reproducibility check, and yield long-term $2\sigma$ RSD precisions (n=109) of 2%, 2.3% and 1.1% for the $^{206}$Pb/$^{238}$U, $^{207}$Pb/$^{235}$U and $^{207}$Pb/$^{206}$Pb ratios respectively (Frei et al. 2006). The raw data is corrected for instrumental mass bias and laser-induced U-Pb fractionation through normalisation to the GJ-1 zircon using in-house data reduction software.

All isotope data were plotted and evaluated using ISOPLOT/EX 3.06 (Ludwig 2003). Model age calculation and error propagation follows Sambridge & Lambert (1997).
U-Pb ion microprobe (SIMS) analyses

High-spatial resolution secondary ion mass spectrometer (SIMS) analyses were made using a Cameca IMS 1270 at the Nordsim facility at the Swedish Museum of Natural History in Stockholm. Detailed descriptions of the analytical procedures for these analyses are given in Whitehouse et al. (1999) and Whitehouse & Kamber (2005). The instrument was operating with a spot size less than 25 µm. Age calculations of isotopic data were made using software Isoplot 3.00 (Ludwig 2003). The amount of common $^{206}$Pb in measured $^{206}$Pb is estimated from $^{204}$Pb assuming a present day terrestrial lead following the model of Stacey & Kramers (1975). Statistical precisions of age estimates are given at the 2σ level (unless otherwise explicitly stated).

References


