# U-Pb zircon age of a massive quartz monzonite from Lillraudok, c. 30 km north-west of Arjeplog, Norrbotten county, Sweden

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Cover: Sample site at Lillraudok east of Laisvikberget (Lájsovárre). Photo: Benno Kathol.

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**ABSTRACT**

The difference in bedrock composition and the structural pattern on either side of lake Hornavan in the Arjeplog area suggest the existence of a major structural break that coincides with the north-west trending lake. The obtained c. 1.80 Ga, late Svecokarelian age of a quartz monzonite from Lillraudok, south of lake Hornavan, considered together with the indirectly received, field-supported early Svecokarelian age of the granite north of the lake, confirms the suggested existence of a major structural break in lake Hornavan. The structural break is either an intrusive contact that truncates the general structural trend to the north-east of the lake or a deformation zone with major amounts of lateral displacement.

**SAMMANFATTNING**

Skillnaden i berggrundens sammansättning och det strukturella mönstret på vardera sidan av sjön Hornavan i Arjeplogområdet tyder på förekomsten av ett större strukturellt brott som sammanfaller med den nordvästligt orienterade sjön. Den erhållna sensvekokarelska åldern, ca 1,80 miljarder år, på en kvartsmonzonit från Lillraudok söder om Hornavan tillsammans med en indirekt erhållen tidigsvekokarelsk ålder för en granit norr om sjön bekräftar den förmodade förekomsten av ett större strukturellt brott i sjön Hornavan. Det strukturella brottet är antingen en intrusivkontakt som klipper den strukturella trenden nordost om Hornavan eller en deformationszon med ett större förskjutningsbelopp.

Keywords: Fennoscandian shield, Svecokarelian orogen, Transscandinavian igneous belt (TIB), radiometric age, zircon, U-Pb, Hornavan

## INTRODUCTION

The Paleoproterozoic bedrock to the south-west of the lake Hornavan is dominated by intrusive rocks which are assigned to the Revsund suite (Högbom 1894, Kathol & Weihed 2005) of the Transscandinavian igneous belt (TIB, Gorbatschev & Bogdanova 1993). The intrusive rocks to the north-east of Hornavan are considered to belong to the 1.88 Ga Perthite monzonite suite or the 1.8 Ga Lina suite. The magnetic anomali map of this area shows mainly narrow, north–south striking structures, which are interpreted to represent bedding in the supracrustal rocks, to the north of the lake, whereas the area south of the lake is dominated by round structures which are interpreted to represent larger, undeformed intrusions. The difference in bedrock composition and structural pattern on either side of Hornavan, which is the deepest lake in Sweden, suggest the existence of a major structural break which is outlined by the lake (Figs. 1–2).

Age determinations of the quartz monzonite at Lillraudok (KBK090023A, Figs. 1–2) south of Hornavan could, together with the dating of a granite south of Labbas (ENT090024X) north of Hornavan, confirm the nature of the structural break at Hornavan. The structural break may be either a major intrusive contact or a major deformation zone, or both. It is also possible that a major deformation zone controlled and confined the northern margin of the intrusion of granitic to quartz monzonitic magmas.

## SAMPLE DESCRIPTION

The sampled rock is a massive, light grey, medium- to coarse-grained, weakly porphyritic quartz monzonite (Fig. 3, Table 1). The sample has been taken in a small quarry close to the forest road east of the mountain Laisvikberget. Results from point-counting of a thin section (Fig. 4) classify the sampled rock as a quartz monzonite in the Streckeisen diagram (LeMaitre 2002). A geochemical analysis places this rock at the border between the syenite and quartz monzonite fields in the TAS-diagram of Middlemost (1985). A mesonormative calculation, using the diagram of

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Sample site for radiometric dating
Thrust within nappe unit
Deformation zone, unspecified

**CALEDONIDES**
**Upper Allochthon, Seve Nappe Complex**
Marble, calc-silicate rock with eclogite to garnet amphibolite
Amphibolite and greenschist
Garnet-mica-schist and quartzo-feldspathic gneiss, marble
Base of Upper Allochthon

**Middle Allochthon**
Meta-arenite with dolerite dykes (Särv Nappe)
Base of Särv Nappe
Meta-arkose, meta-greywacke, mica-schist, quartzite, phyllite
Phyllite, phyllonite, meta-greywacke, meta-arkose, quartzite
Granite, syenite, monzonite, tonalite
Base of Middle Allochthon

**Lower Allochthon**
Phyllite, in part graphitic, greywacke and mudstone
Alum shale and graphite phyllite
Quartzite, quartz arenite, mudstone and phyllite
Proterozoic granitoid
Base of Lower Allochthon

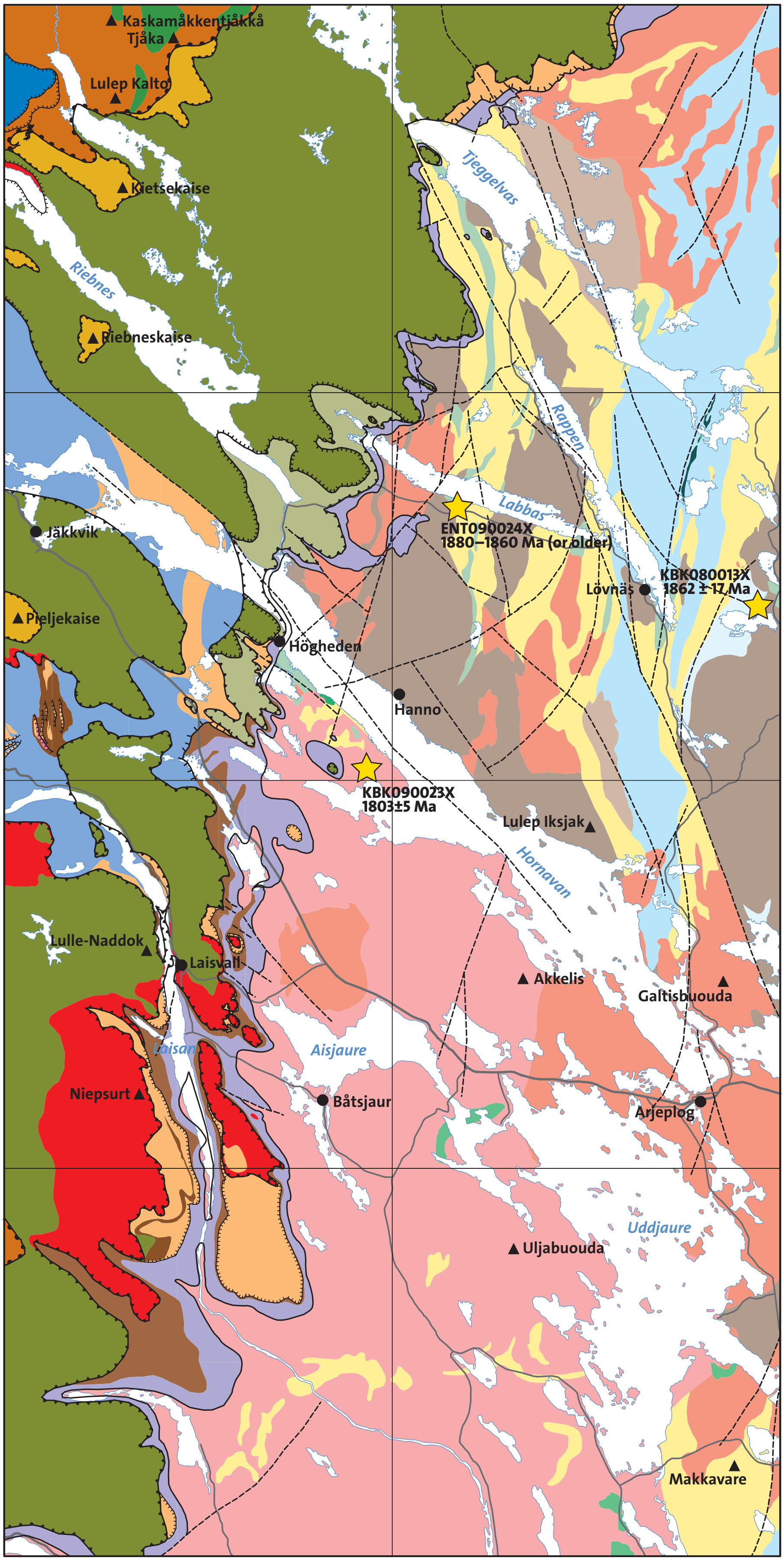
**AUTOCHTHONOUS SEDIMENTARY COVER**
Alum shale and mudstone
Quartz arenite, quartzite and mudstone
Major unconformity

**FENNOSCANDIAN SHIELD**
**Late to post Svecokarelian intrusive rocks**
Granite to quartz monzonite, monzonite, Revsund suite
Gabbro, ultramafic rock, Revsund suite
Granite, Lina suite

**Early Svecokarelian intrusive rocks**
Granite, Perthite monzonite suite
Diorite to gabbro, Perthite monzonite suite
Granite to tonalite, Jörn GI suite

**Svecofennian supracrustal rocks**
Sandstone, siltstone, greywacke; Snavva-Sjöfallet group
Banded iron formation
Rhyolite to dacite, Arvidsjaur group
Andesite to basalt, Arvidsjaur group
Meta-greywacke, meta-argillite, paragneiss, Bothnian supergroup

Figure 1. Preliminary geological map of map areas 26H Jäkkvik and 25H Arjeplog. The sample sites for radiometric datings, cited in the text, are marked by yellow stars.



Kaskamåkkentjåkkå
Tjåka
Lulep Kalto
Kietsekaise
Riebnes
Riebneskaise
Tjeggelvas
Rappen
Labbas
ENT090024X
1880–1860 Ma (or older)
Jäkkvik
Lövnäs
KBK080013X
1862 ± 17 Ma
Pieljekaise
Högheden
Hanno
KBK090023X
1803±5 Ma
Lulep Iksjak
Hornavan
Lulle-Naddok
Laisvall
Akkelis
Galtisbuouda
Laisan
Aisjaure
Niepsurt
Båtsjaur
Arjeplog
Uddjaure
Uljabuouda
Makkavare

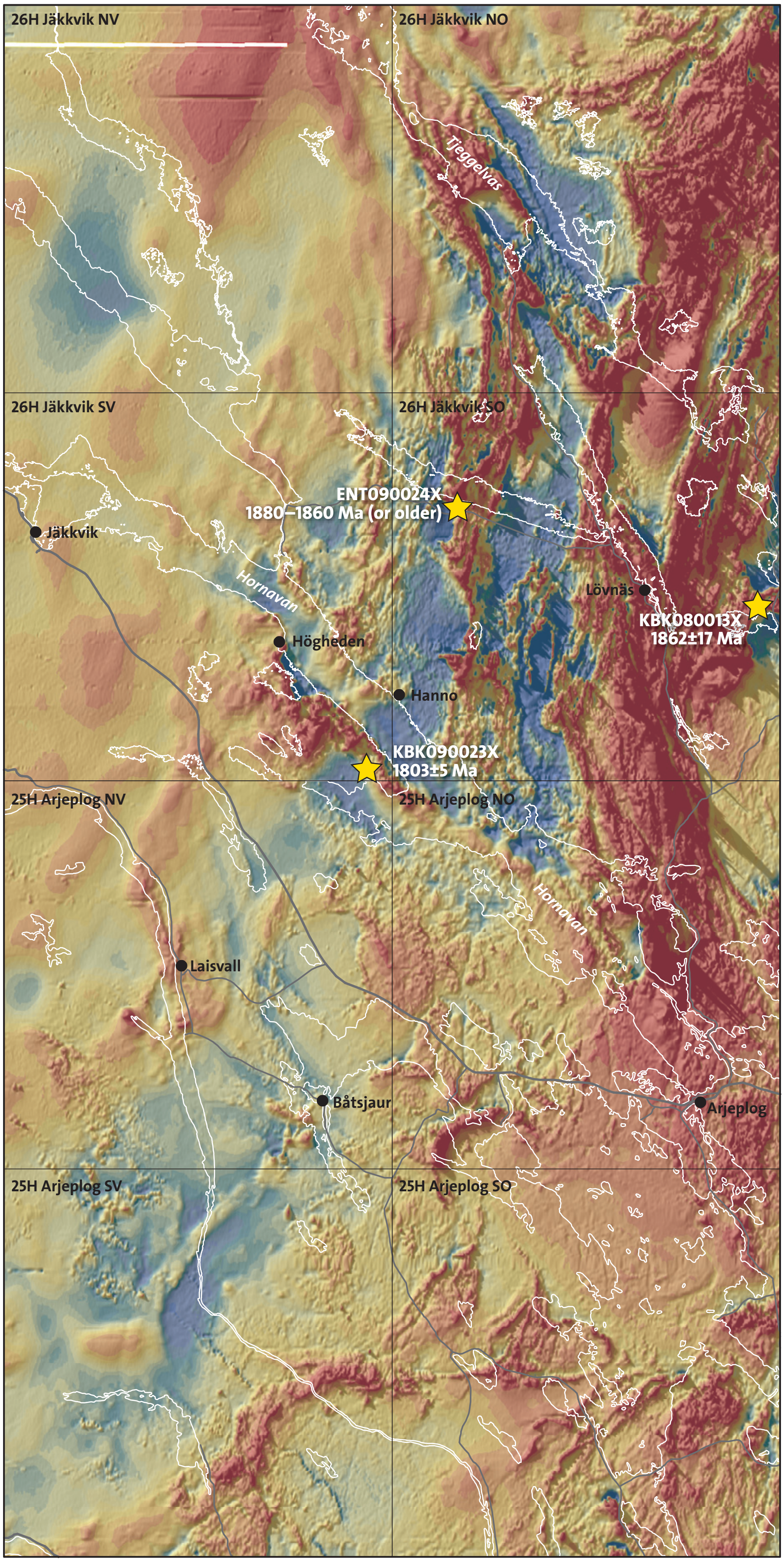



Figure 2. Magnetic anomaly map of map areas 26H Jäkkvik and 25H Arjeplog. The sample sites for radiometric datings, cited in the text, are marked by yellow stars.

Table 1. Summary of sample data.

| | |
|---|---|
| Rock: | Quartz monzonite |
| Tectonic domain: | Svecokarelian orogen |
| Tectonic subdomain: | Bothnia–Skellefteå lithotectonic unit |
| Lithodemic unit: | Late to post Svecokarelian intrusive rocks, GSDG c. 1.81–1.76 Ga, TIB 1 |
| Lithodemic subunit: | Revsund suite |
| Sample number: | KBK090023X |
| Lab-id number: | n3582 |
| Coordinates: | 7349445/609001 (Sweref 99TM), 7350588/1572869 (RT90) |
| Map sheet: | 734-60-11 (Sweref 99TM) 26H Jäkkvik 0 e (RT90) |
| Locality: | Lillraudok |
| Project: | Jäkkvik–Boden |

Figure 3. The dated quartz monzonite from Lillraudok east of Laisvikberget, map area 26H Jäkkvik SO.

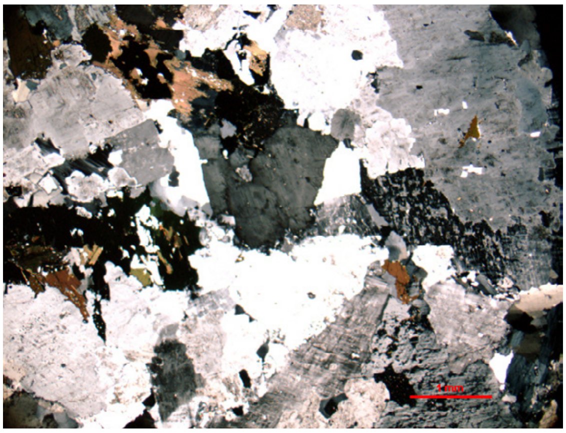


Figure 4. Photomicrograph of the quartz monzonite from Lillraudok.

LeMaitre (2002), suggests a quartz monzonitic composition. The composition is within the igneous spectrum of Hughes (1973).

## 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 back-scatter electron (BSE) imaging using electron microscopy at the Department of Geology, Lund University. High-spatial resolution secondary ion mass spectrometer (SIMS) analysis was done in 2010 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 a modern common lead composition (Stacey & Kramers 1975) and the 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).

Zircon grains in the heavy mineral concentrate have subhedral to euhedral prismatic shapes and light pinkish colour. There are also angular fragments of zircon. Most grains have inclusions and cracks and are generally turbid, but there are also transparent grains which were selected for analysis. BSE images show an internal oscillatory zonation in the selected zircons (Fig. 5).

The uranium content of the analysed zircon varies between 105 and 339 ppm and Th/U ratios are 0.22–0.31 (n = 8, Table 2). The data points are concordant and yield a concordia age of 1803±5 Ma (2σ, MSWD = 4.5), similar to the weighted average $^{207}Pb/^{206}Pb$ age of 1800±10 Ma (95% confidence, MSWD = 2.0). The concordia age of 1803±5 Ma (Fig. 6) is interpreted to date igneous crystallisation of the studied quartz monzonite.

## DISCUSSION AND CONCLUSION

The assignment of the intrusive rocks south-west of the lake Hornavan to the late Svecokarelian Revsund suite (Högbom 1894, Kathol & Weihed 2005) is consistent with the obtained age of 1803±5 Ma for the quartz monzonite from Lillraudok.

A granite intrusion that occurs just north of Hornavan, between Hanno and the lake Labbas, has previously been included into the late Svecokarelian Lina suite (granite, pegmatite, 1.85–1.75 Ga, Koistinen et al. 2001, Bergman et al. 2012). An attempt to date this intrusion has been made on a sample (ENT090024X) taken in a quarry to the south of Labbas (Fig. 1). No direct crystallisation age could be obtained from the sampled rock at this place. However, the analysis shows that the granite underwent some kind of event at c. 1860 Ma and it must thus be older than the Lina suite.

Indications for an early Svecokarelian age of the named granite intrusion have also been observed in the field. To the west of Guorbavare, close to Hanno, inclusions of fine-grained felsic, quartz-porphyritic, probably subvolcanic rocks occur within medium-grained, weakly porphyritic granite. The fine-grained rock of the inclusions contains sparsely distributed, larger grains of potassium feldspar. These grains are interpreted to be derived from the surrounding granite, which suggests that the inclusions are enclaves. Furthermore, this suggests magma mingling between the medium-grained granite and the fine-grained rock. Therefore, if the granite belongs to the Lina suite, the enclaves must be of the same age. However, volcanic or subvolcanic rocks of that age have not been observed in the county of Norrbotten. On the other hand, a subvolcanic intrusion at Rimpos (KBK080013X, Figs. 1–2) to the east of Guorbavare has been dated at c. 1.86 Ga and assigned to the Svecofennian, 1.88–1.86 Ga old Arvidsjaur group (unpublished data in Kathol et al. 2010). Additional evidence for this early Svecokarelian age of the granite at Labbas is that both the granite and the fine-grained rock of the enclaves are recrystallised. Denoting these rocks to the Lina suite would require a thermal event that postdates the intrusion of the c. 1.80 Ga old Lina suite.

In summary, the above mentioned ages and field observations suggest that the granite intrusion between the lakes Hornavan and Labbas has an early Svecokarelian age. Here it is included within the 1.88–1.86 Ga old Perthite monzonite suite (Witschard 1984). Together with the age of the granite at the quarry south of Labbas, the obtained age of the quartz monzonite from Lillraudok confirms the suggested existence of a major structural break in Hornavan. We cannot distinguish whether it is an intrusive contact or a deformation zone, or both. If the structural break is interpreted to result solely from a deformation zone, major amounts of lateral displacement are required to explain the difference in structure on either side of Hornavan.

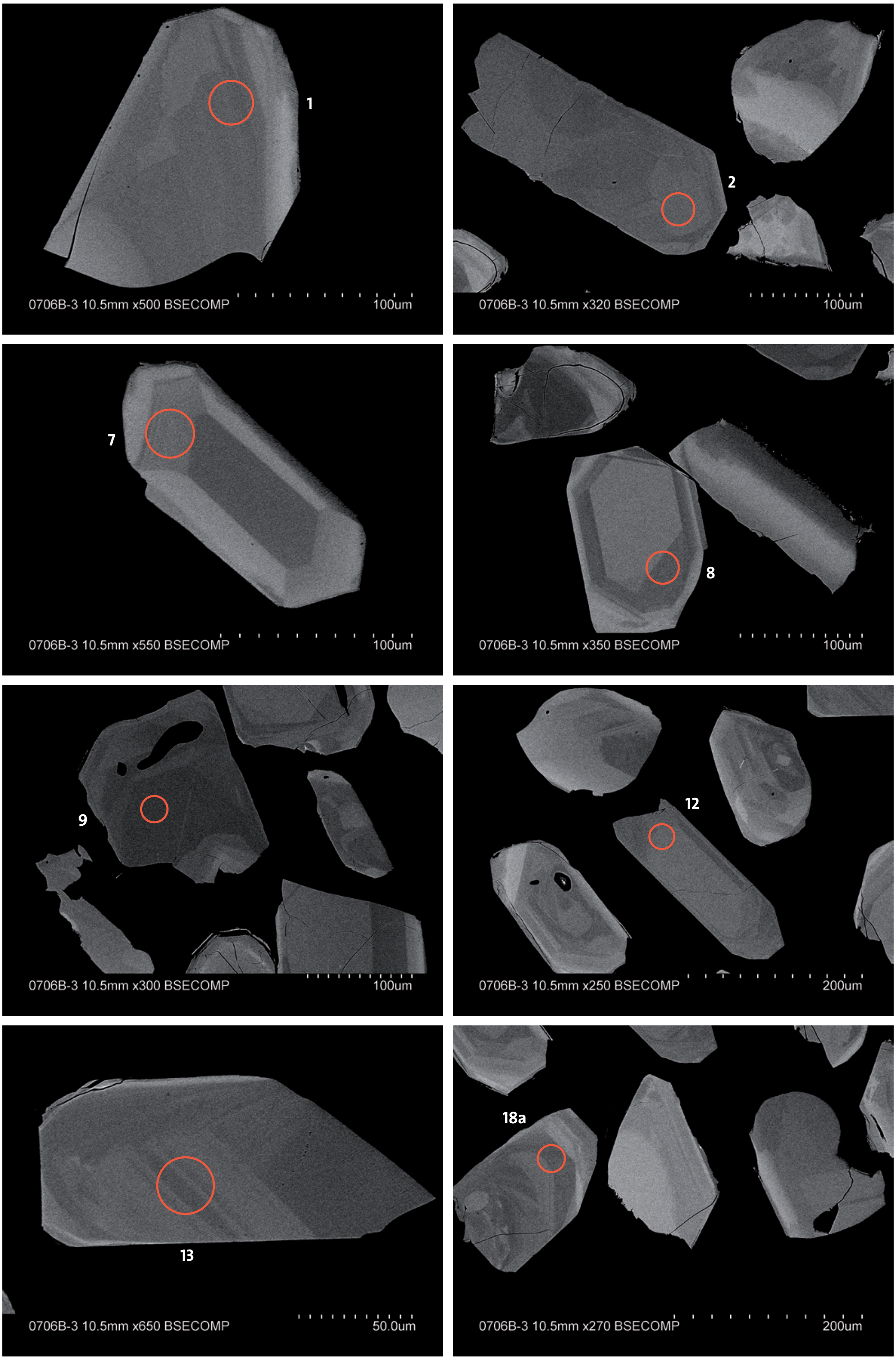



Figure 5. Back-scatter electron images of zircon from the dated sample. Red circles mark the approximate location of analysed spots. Numbers refer to analytical spot number in Table 2. BSE-image: Andreas Petersson.

Table 2. SIMS U-Pb-Th zircon data (KBK090023X, n3582).

| Sample/spot number | U (ppm) | Th (ppm) | Pb (ppm) | Th/U calc.[1] | $^{206}Pb/^{204}Pb$ measured | $f_{206}$%[2] | $^{238}U/^{206}Pb$ | ±σ (%) | $^{207}Pb/^{206}Pb$ | ±σ (%) | $^{207}Pb/^{206}Pb$ age (Ma) | ±σ | $^{206}Pb/^{238}U$ age (Ma) | ±σ | Disc. % 2σ lim.[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| n3582-1 | 197 | 47 | 75 | 0,23 | 98593 | {0.02} | 3,099 | 0,96 | 0,1092 | 0,48 | 1785 | 9 | 1803 | 15 | |
| n3582-2 | 203 | 54 | 79 | 0,26 | 63320 | {0.03} | 3,040 | 0,95 | 0,1092 | 0,47 | 1786 | 8 | 1833 | 15 | 0,09 |
| n3582-7 | 339 | 97 | 130 | 0,27 | 118998 | {0.02} | 3,117 | 0,95 | 0,1106 | 0,41 | 1809 | 7 | 1794 | 15 | |
| n3582-8 | 260 | 67 | 100 | 0,25 | 110577 | {0.02} | 3,073 | 0,96 | 0,1109 | 0,41 | 1815 | 7 | 1816 | 15 | |
| n3582-9 | 105 | 24 | 40 | 0,22 | 65379 | {0.03} | 3,094 | 0,95 | 0,1113 | 0,75 | 1821 | 14 | 1805 | 15 | |
| n3582-12 | 224 | 71 | 87 | 0,31 | 62025 | {0.03} | 3,085 | 0,96 | 0,1100 | 0,44 | 1800 | 8 | 1810 | 15 | |
| n3582-13 | 152 | 36 | 58 | 0,23 | 40325 | {0.05} | 3,096 | 1,03 | 0,1096 | 0,55 | 1794 | 10 | 1804 | 16 | |
| n3582-18a | 181 | 43 | 70 | 0,24 | 103024 | {0.02} | 3,031 | 0,96 | 0,1097 | 0,50 | 1794 | 9 | 1838 | 15 | |

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

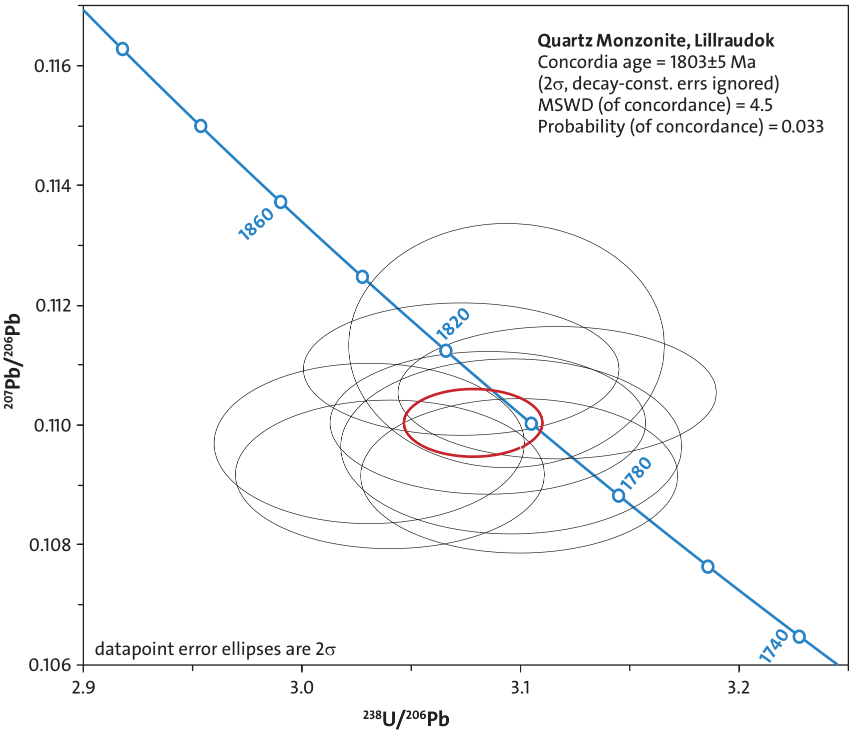



Figure 6. Terra Wasserburg diagram showing U-Pb SIMS zircon data.


## ACKNOWLEDGMENTS

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