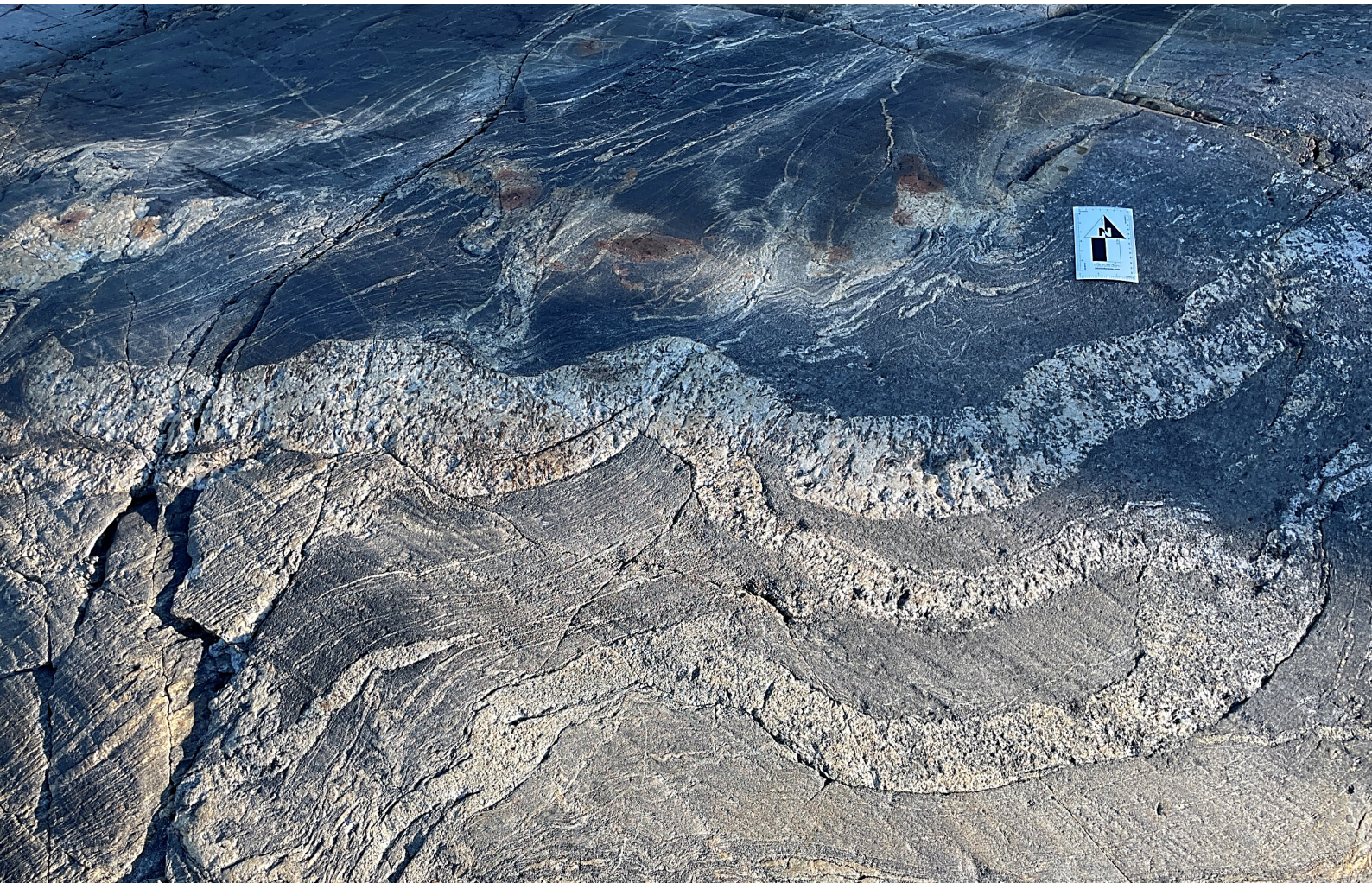


Insights into Paleoproterozoic magmatic and migmatisation events using U–Pb zircon age dating in Västernorrland, Sweden



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Abstract

The Geological Survey of Sweden (SGU) had initiated several multidisciplinary mapping projects in Sweden as part of the authority's long-term plan for the period 2021–2027. Some of these projects focus on mapping known ore-bearing areas ("brown fields") while others emphasise systematic, thematic mapping of energy, battery and innovation critical mineral and metals. These projects have a direct societal impact on the transition to green energy, the development of new technology and Agenda 2030.

In Västernorrland County (the study area), the main objective is to update the geological, geophysical and geochemical characteristics of rocks. The goal is to document and interpret lithology, supracrustal succession, structure and the formation of Li, Sn, W, Nb and Ta mineralisation and their relations to the different lithologies, particularly granitoids. Samples for new U-Pb age dating were collected during 2021–2023 as part of the southern Västernorrland mapping project. The new zircon U-Pb age data carried out on seven granites, two granodiorites, two migmatites, three felsic volcanic rock and one amphibolite contribute to better understand the origin of the various intrusive suites, their emplacement ages, and the timing of the melt-producing events which occur in the southern part of the Västernorrland area.

The results from the felsic intrusive rocks (granite and granodiorite) indicate at least two different suite emplacements at ca. 1.94 Ga and ca. 1.88–1.86 Ga and show a strong Archaean inheritance signature. The migmatised samples recorded both a migmatisation event at 1.86 Ga, and the probable magmatic crystallisation age of their protolith (of igneous origin) at 1.98 Ga. These findings suggest that older magmatic activities than so far reported occurred in this area. The three felsic volcanic rocks ranging in composition from rhyolite to dacite, yielded two emplacement ages at 1.98 Ga and 1.87 Ga (two samples). This result also suggests that volcanic activity in this area may have occurred earlier than previously known, at approximately 1.98 Ga.

Keywords: Västernorrland, U/Pb zircon dating, Plutonic suites emplaced, Felsic volcanic emplacement, Migmatisation

Sammanfattning

Sveriges geologiska undersökning (SGU) har påbörjat flera tvärvetenskapliga projekt i Sverige, som en del av myndighetens långtidsplan för perioden 2021–2027. Några av dessa projekt fokuserar på kartering av kända malmförekomster, medan andra lägger tonvikten på systematisk, tematisk kartläggning av energi-, batteri- och innovationskritiska mineral och metaller. Dessa projekt har en direkt samhällspåverkan gällande omställningen till grön energi, utvecklingen av ny teknologi och Agenda 2030.

I Västernorrlands län (projektområdet) är huvudsyftet att uppdatera underlaget för de geologiska, geofysiska och geokemiska egenskaperna hos berggrunden. Detta innebär dokumentation och tolkning av litologier, suprakrustala successioner och strukturer, samt bildningen av mineraliseringar av litium, tenn, volfram, niob och tantal och deras relation till olika litologier, i synnerhet till granitoider. Prover för nya U-Pb åldersdateringar samlades in perioden 2021–2023 under berggrundskarteringen av södra delen av Västernorrlands län. De nya U-Pb åldersdateringarna som utfördes på sju graniter, två granodioriter, två migmatiter, tre felsiska vulkaniter och en amfibolit, bidrar till en bättre förståelse av ursprunget hos de olika intrusiva sviterna, deras bildningssåldrar och tiden för de migmatitomvandlingar som förekommit i Västernorrlands läns södra del.

Resultaten från de felsiska intrusivbergarterna (graniter och granodioriter) pekar på minst två olika sviter av intrusioner, en vid ca 1,94 Ga och en vid ca 1,88–1,86 Ga, och visar dessutom en tydlig arvssignatur från arkeisk tid. De migmatitiserade proven visade både en migmatiseringshändelse vid 1,86 Ga och en sannolik magmatisk kristallisationsålder av dess protolit (av magmatiskt ursprung) vid 1,98 Ga. Dessa resultat tyder på att äldre magmatisk aktivitet förekommit än vad som tidigare har dokumenterats i området. De tre felsiska vulkaniterna, med ryolitisk till dacitisk sammansättning, visade två bildningsåldrar vid 1,98 Ga och 1,87 Ga (två prover). Dessa resultat tyder också på att vulkanisk aktivitet kan ha skett inom detta område och indikerar en tidigare okänd vulkanisk aktivitet omkring 1,98 Ga.

Nyckelord: Västernorrland, U-Pb zirkondatering, Intrusionsåldrar av plutoniska sviter, Bildningsåldrar av felsiska vulkaniter, Migmatitomvandling

Introduction

The Västernorrland area is situated in the southern part of the Bothnia–Skellefteå lithotectonic unit, a regionally extensive Paleoproterozoic sedimentary–volcanic domain occurring in central and northern Sweden (Fig. 1; e.g., Skyttå et al. 2020, and references therein). This area is separated from the Ljusdal lithotectonic unit to the south (Högdahl & Bergman 2020) by the Hassela Shear Zone and its precursor high-grade shear belt known as the proto-Hassela Shear Zone or the “Granite and Diatexite Belt”, the latter extends northwestwards into the ‘Transition Belt’ (Gorbatshev et al. 1997; Högdahl & Sjöström 2001; Högdahl et al. 2001, 2008, 2012; Fig. 1). This southern boundary marks a major structural break and a significant lithological change in the Svecokarelian orogen in Sweden.

The Bothnia–Skellefteå lithotectonic unit is predominantly composed of metamorphosed siliciclastic sedimentary rocks, primarily deposited as turbiditic wacke and argillite in the submarine Bothnian basin between 1.96 (or earlier) and 1.86 Ga. These sediments are interleaved with mafic to felsic volcanic rocks emplaced between 1.91–1.87 Ga (Fig. 2). The unit is intruded by various plutonic suites emplaced during the intervals 1.96–1.92 Ga, 1.91–1.87 Ga and 1.81–1.76 Ga (Fig. 2).

Polyphase ductile deformation and metamorphism under variable temperatures and low-pressure conditions, including crustal melting, the formation of migmatite, and the associated emplacement of granitic rocks, occurred throughout the Bothnia–Skellefteå lithotectonic unit during the period 1.88–1.85 Ga.

The main objective of the Västernorrland Project is to update the geological, geophysical, and geochemical characteristics of rocks in the study area (Fig. 2). This includes new mapping both locally and along regional transects to document and interpret the lithology, supracrustal succession, structural features, and the formation of pegmatite-related Li, Sn, W, Nb, and Ta mineralisation, as well as their relationships to different lithologies, particularly granitoids (Sadeghi et al., 2022).

The Västernorrland mapping project began in 2021, and this report presents only the age-dating work conducted between 2021 and 2023 in the southern part of the Västernorrland area. Fifteen samples were selected for U-Pb dating. These samples represent various types of intrusive rocks, including nine felsic plutonic rocks, four intermediates to felsic volcanic rocks, and two migmatite samples (Fig. 2, Table 1).

Deciphering the origins of these intrusive suites, their emplacement ages, and the timing of melt-producing events is crucial for better understanding their connection to the Svecokarelian orogeny and their potential implications for the formation of LCT (Lithium-Cesium-Tantalum) pegmatites.

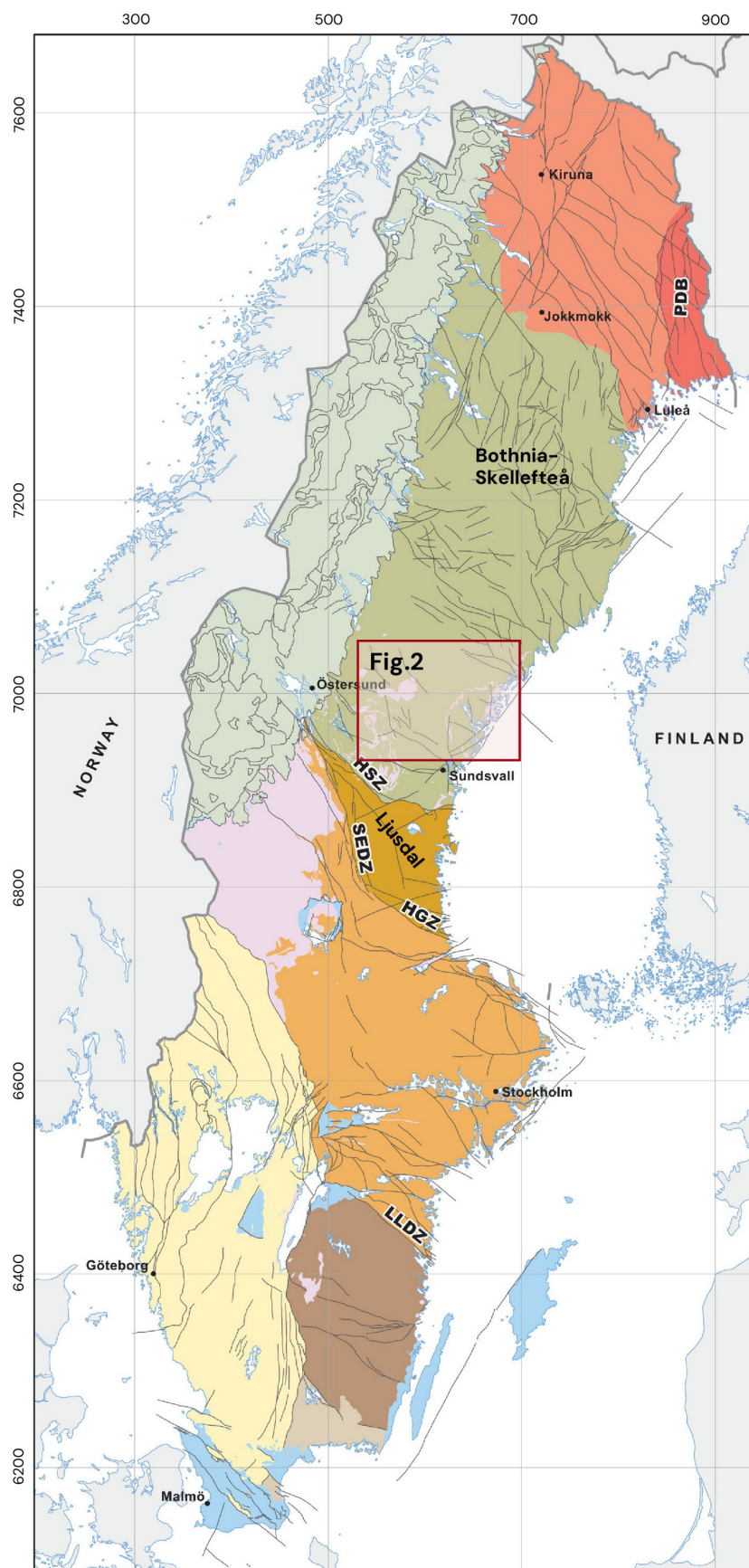


Figure 1. Lithotectonic units inside the Swedish part of the 2.0–1.8 Ga Svecokarelian orogen (after Skyttä et al. 2020)

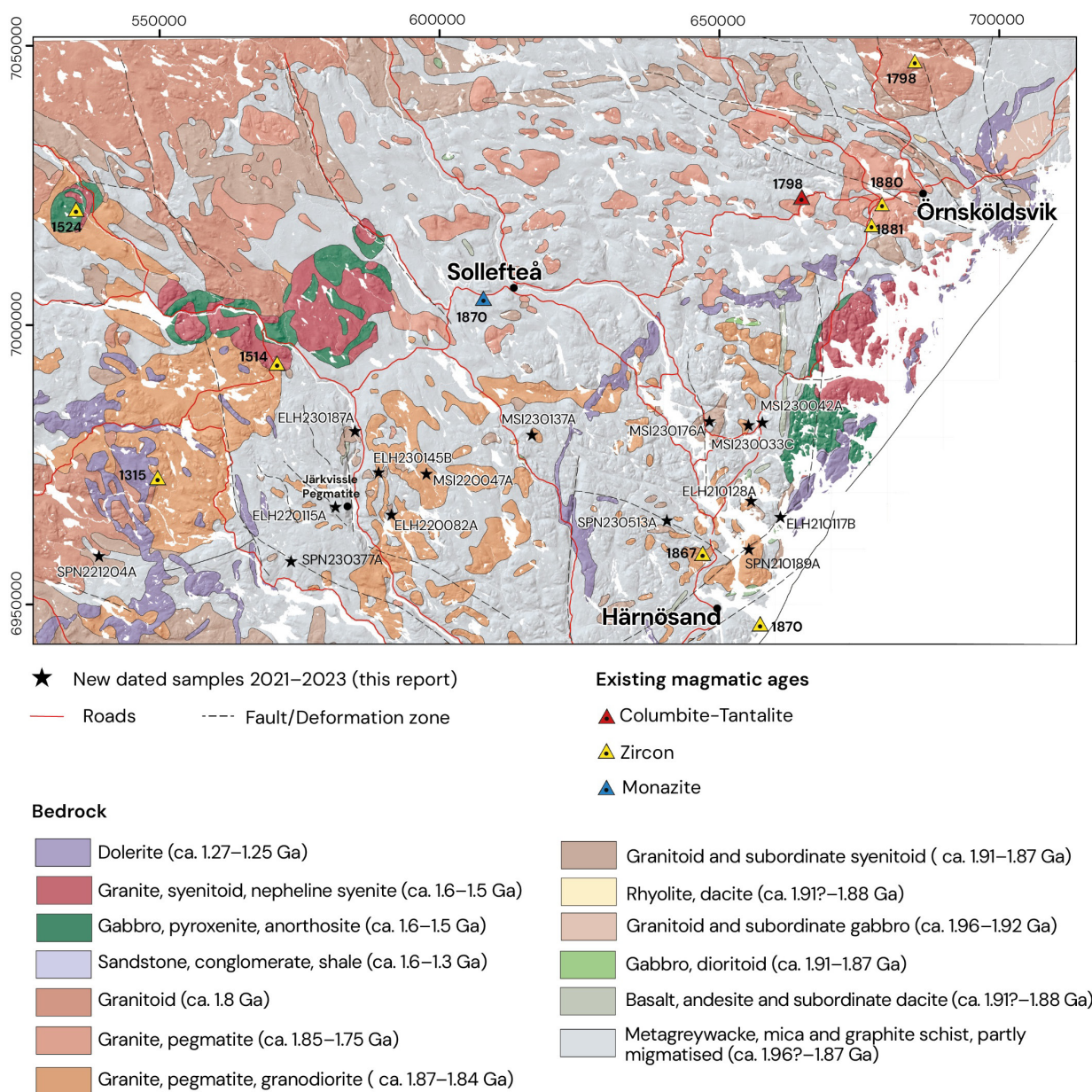


Figure 2. Simplified geological map of the study area and locations and label of samples for separated zircon dating. (Background geological map refers to 1:1 million scale geological map at SGU with some preliminary modification of granitoids ages in study area). Coordinate system: SWEREF99_TM.

Table 1. Summary of data.

Sample number	Rock	Tectonic domain	Tectonic subdomain	Lab-id number (Nordsim)	Coordinates (SWEREF 99TM)	Map sheet (SWEREF 99TM)	Map sheet (RT90)	Locality	Project
ELH220115A	Granite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2022/23	6967527/581424	696_58_50	18G3i	Gammfäbod-berget	Västernorrland
ELH220082A	Granite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2022/23	6966118/591423	696_59_50	18H3a	Norr om Burtjärnen	Västernorrland
SPN210189A	Granite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2022/23	6959956/655277	695_65_55	18I2c	Dalomsberget	Västernorrland
MSI220047A	Granite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2022/23	6973451/597659	697_59_05	18H4b	Nordansjö-höjden	Västernorrland
MSI230042A	Granite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2023/24	6982194/655190	698_65_05	18I6j	Lill-Gälings-berget	Västernorrland
ELH230145B	Micro-granite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2023/24	6973669/589120	697_58_05	18G4j	Sör-Nysjön	Västernorrland
SPN230513A	Granodiorite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2023/24	6965118/640632	696_64_50	18H3j	Gammfädbod-berget	Västernorrland
ELH230187A	Granodiorite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2023/24	6981090/584914	698_58_05	18G6i	Hölleforsen	Västernorrland
MSI230176A	Granodiorite to tonalite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2023/24	6982801/ 648247	698_64_05	18I6b	Edsbacken	Västernorrland

Table 1. Continued.

Sample number	Rock	Tectonic domain	Tectonic subdomain	Lab-id number (Nordsim)	Coordinates (SWEREF 99TM)	Map sheet (SWEREF 99TM)	Map sheet (RT90)	Locality	Project
SPN230377A	Diatexite migmatite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2023/24	6957769/573469	695_57_50	18G1g	Kroketjärnen	Västernorrland
MSI230137A	Leucosome of migmatite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2023/24	6980433/616549	698_61_05	18H6f	Skorrmyrhöjden	Västernorrland
SPN221204A	Meta rhyolite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2022/23	6 958718/539176	695_53_55	18F2j	Gråssjön	Västernorrland
MSI230033C	Meta rhyolite-dacite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2023/24	6982647/657719	698_65_05	18I6d	Dala-Gårdbergs-myran	Västernorrland
ELH210128A	Meta dacite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2022/23	6968580/655667	696_65_55	18I3c	Sörholmen	Västernorrland
ELH210117B	Amphibolite	Svecokarelian orogen	Bothnia–Skellefteå lithotectonic unit	NS-2022/23	6965709/660931	696_66_50	18I3d	Halsviken	Västernorrland

Sample description

Among the felsic plutonic rocks, five samples were taken in the vicinity of the Järkvissle granite and pegmatite dominated field (ELH220115A, ELH220082A, MSI220047A, ELH230145B and ELH230187A) and four samples around Härnösand mainly in the northern part of this area (SPN210189A, MSI230042A, SPN230513A and MSI230176A). Three samples representing metavolcanic rock (ELH210128A, ELH210117B and MSI230033C) were taken from the northern part of the Härnösand area and one sample (SPN221204A) from the westernmost part of the Västernorrland area. The migmatitic samples (SPN230377A and MSI230137A) were taken in the circumference of the Järkvissle pegmatite: one sample (MSI230137A) comes from ~30 km northeast of Järkvissle, while the other sample (SPN230377A) was collected 10 km southwest of Järkvissle, adjacent to a major NW-SE deformation zone.

Sample ELH220115A

Sample ELH220115A is a leucocratic, medium- to coarse-grained (ca. 1–7 mm) granitic rock that is weakly foliated (Fig. 3A). Although the granite is typically equigranular, locally it also contains irregular pegmatite patches or zones that are typically massive and show narrow, weakly defined transitional contacts with granitic parts. The dated granitic sample consists essentially of K-feldspar (orthoclase), plagioclase, quartz, biotite, and white mica (Fig. 4A–B). Accessory minerals include zircon, allanite, and Fe-Ti oxides. K-feldspar occurs as euhedral to subhedral tabular crystals and exhibits sericitic alteration (Fig. 4A–B). The sericitisation is also affecting some of the plagioclase and is associated with alteration of biotite to chlorite. Quartz exhibits amoeboid grains, some of which are composed of multiple subgrains, indicating combined grain boundary migration and subgrain rotation recrystallisation. Evidence of bulging recrystallisation is also observed (Fig. 4B).

Sample ELH220082A

Sample ELH220082A is a granitic rock with a medium to coarse-grained (ca. 4 mm) texture and is weakly foliated (Fig. 3B). The sample consists essentially of K-feldspar (orthoclase), plagioclase, quartz, biotite, and white mica (Fig. 4C–D). Accessory minerals include zircon, allanite, and Fe-Ti oxides. K-feldspar occurs as euhedral to subhedral tabular crystals and displays a sericitic alteration (Fig. 4C–D). In the plagioclase, the sericitisation is generally unevenly developed within individual crystals, and is characteristically confined to the central calcic core of the grains, or to specific zones of the crystals, and is usually surrounded by and in sharp contact with clear unaltered marginal domains (Fig. 4D). Quartz exhibits irregular grain boundaries in polycrystalline aggregates which is caused by grain boundary migration recrystallisation (Fig. 4D). Locally, the rock is crosscut by generally massive, aplitic-pegmatitic bands or veins, sometimes containing greenish-blue apatite (Fig. 3B).

Sample SPN210189A

Sample SPN210189A is a granitic rock with an equigranular medium to coarse-grained (ca. 3 mm) texture (Fig. 3C). The sample consists essentially of K-feldspar, plagioclase, quartz, white mica, chlorite, and minor biotite (Fig. 4E–F). Accessory minerals include zircon. K-feldspar is the most abundant phase and occurs as subhedral crystals of microcline which display crosshatch twinning and slight sericitic alteration (Fig. 4E–F). In the plagioclase, the sericitisation is generally unevenly developed within individual crystals, and is characteristically confined to the central calcic core of the grains, or to specific zones of the crystals, and is usually surrounded by and in sharp contact

with clear unaltered marginal domains (Fig. 4F). The replacement of plagioclase by sericite is associated with alteration of biotite and muscovite to chlorite. Quartz exhibits amoeboid grains, partly consisting of several subgrains, which suggests combined grain boundary migration and subgrain rotation recrystallisation, respectively. Bulging recrystallisation can also be observed (Fig. 4F).

Sample MSI220047A

Sample MSI220047A is a foliated granitic rock with a medium-grained (ca. 1 mm) texture and locally with mafic enclaves (Fig. 3D). The sample consists essentially of K-feldspar, plagioclase, quartz, biotite, chlorite and white mica (Fig. 4G–H). Accessory minerals include zircon, allanite, and Fe-Ti oxides. K-feldspar occurs as subhedral crystals and displays perthitic texture and sericitic alteration (Fig. 4G–H). In the plagioclase, the sericitisation is generally unevenly developed within individual crystals, and is characteristically confined to the central calcic core of the grains, or to specific zones of the crystals, and is usually surrounded by and in sharp contact with clear unaltered marginal domains (Fig. 4H). The replacement of plagioclase by sericite is associated with alteration of biotite to chlorite. Quartz exhibits amoeboid grains, partly consisting of several subgrains, which suggests combined grain boundary migration and subgrain rotation recrystallisation, respectively. Bulging recrystallisation can also be observed (Fig. 4H).

Sample MSI230042A

Sample MSI230042A is a granitic rock with an equigranular medium to coarse-grained (ca. 3 mm) texture (Fig. 3E). The sample consists essentially of K-feldspar, plagioclase, quartz, white mica, chlorite, and minor biotite (Fig. 5A–B). K-feldspar is the most abundant phase and occurs as subhedral crystals of microcline which display crosshatch twinning and slight sericitic alteration (Fig. 5A–B). Plagioclase is also partially replaced by sericite. Quartz exhibits amoeboid grains, partly consisting of several subgrains, which suggests combined grain boundary migration and subgrain rotation recrystallisation, respectively (Fig. 5B).

Sample ELH230145B

Sample ELH230145B is a weakly foliated micro-granite occurring as a 0.6 m wide, subvertical dyke that crosscuts both migmatitic metasedimentary rocks and a foliated biotite granitoid. The rock has an equigranular, fine to medium-grained (ca. 1 mm) granitic texture (Fig. 3F). The foliation is mainly marked by oriented biotite but also recrystallized bands of quartz, plagioclase, and alkali feldspar (mainly microcline) (Fig. 5C–D). The sample consists essentially of K-feldspar, plagioclase, quartz, and biotite. K-feldspar occurs as subhedral crystals of microcline which display crosshatch twinning (Fig. 5C–D). Quartz exhibits dominant bulging recrystallisation (Fig. 5D).

Sample SPN230513A

Sample SPN230513A is a weakly foliated granodioritic rock with a medium to coarse-grained (ca. 3 mm) texture (Fig. 3G). The sample consists essentially of K-feldspar, plagioclase, quartz, and biotite (Fig. 5E–F). Accessory minerals include apatite, zircon and Fe-Ti oxides. Foliation is mainly marked by oriented biotite and recrystallized bands of quartz, plagioclase, and apatite (Fig. 5E–F). The sericitic alteration is not strongly developed but affects both K-feldspar and plagioclase. Quartz exhibits dominant subgrain rotation recrystallisation (Fig. 5F).

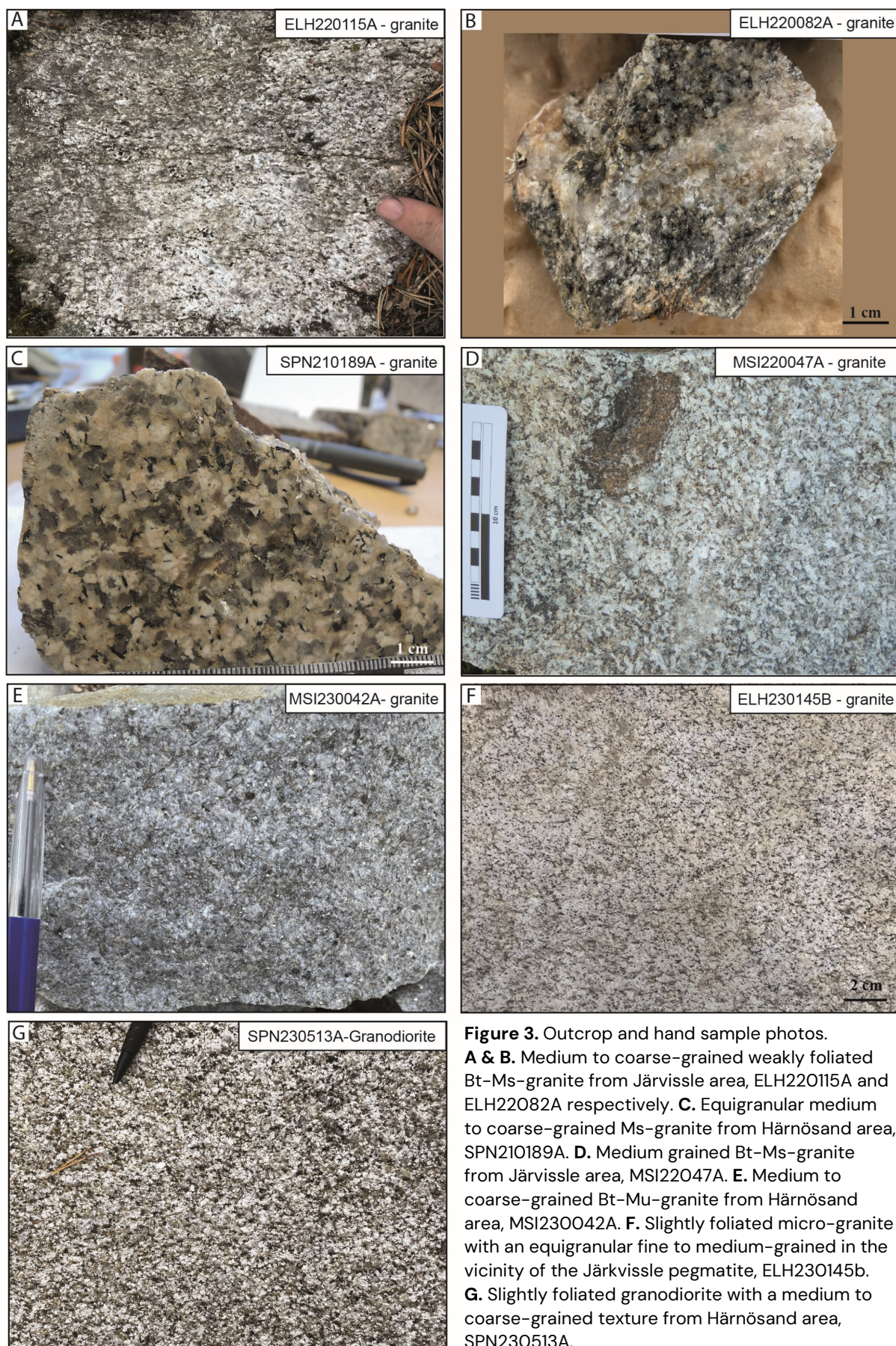


Figure 3. Outcrop and hand sample photos. **A & B.** Medium to coarse-grained weakly foliated Bt-Ms-granite from Järvissle area, ELH220115A and ELH220082A respectively. **C.** Equigranular medium to coarse-grained Ms-granite from Härnösand area, SPN210189A. **D.** Medium grained Bt-Ms-granite from Järvissle area, MSI220047A. **E.** Medium to coarse-grained Bt-Mu-granite from Härnösand area, MSI230042A. **F.** Slightly foliated micro-granite with an equigranular fine to medium-grained in the vicinity of the Järvissle pegmatite, ELH230145b. **G.** Slightly foliated granodiorite with a medium to coarse-grained texture from Härnösand area, SPN230513A.

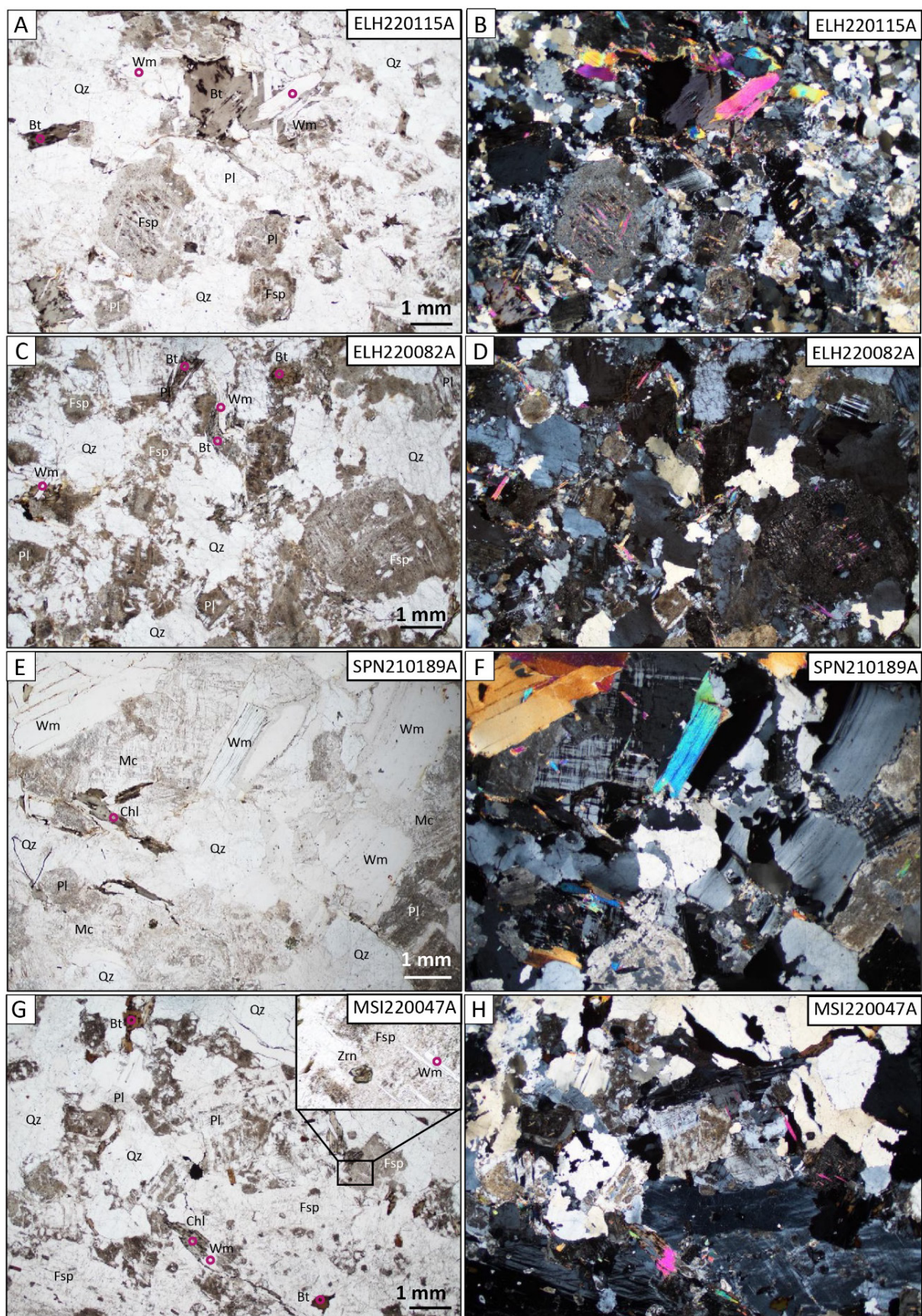


Figure 4. Optical microscope images in plane polarised light (left) and cross-polarised light (right) of the granitic rocks in Fig. 3A–D. Abbreviations: Bt = Biotite, Chl = Chlorite, Fsp = K-feldspar, Mc = Microcline, Pl = Plagioclase, Qtz = Quartz, Wm = white mica, Zrn = Zircon.

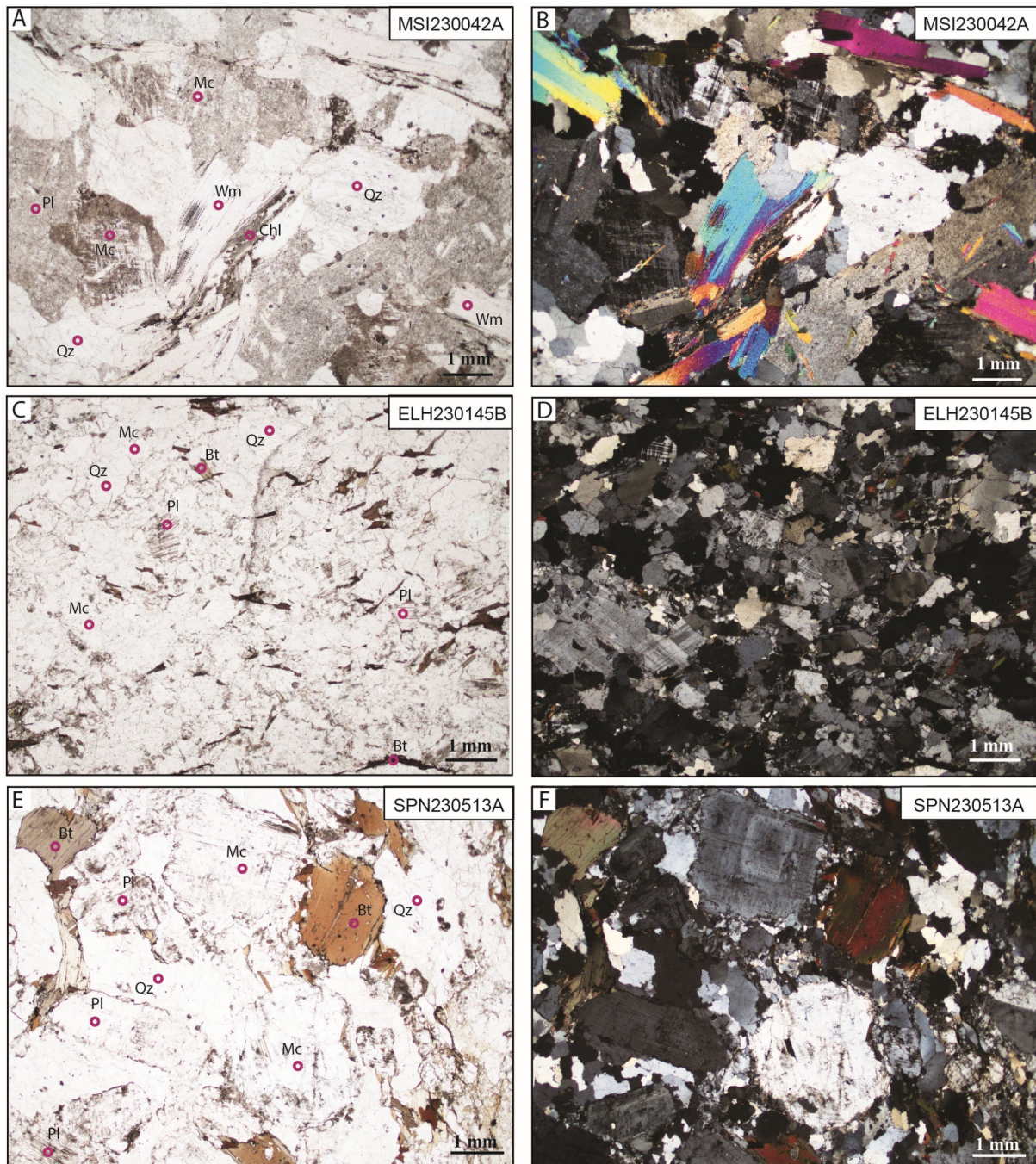


Figure 5. Optical microscope image in plane polarised light (left) and cross-polarised light (right) of the granitic to granodioritic rocks in Fig. 3E–G. Abbreviations: Bt = Biotite, Chl = Chlorite, Mc = Microcline, Pl = Plagioclase, Qtz = Quartz, Wm = white mica.

Sample ELH230187A

Sample ELH230187A is a foliated, feldspar-phyrlic granodioritic to granitic rock with a medium to coarse-grained (ca. 1–10 mm) equigranular to porphyritic texture (Fig. 6A). Locally, the granitoid contains biotite-rich lenticular seams and enclaves. The sample consists essentially of plagioclase, quartz, amphibole and biotite (Fig. 7A–B). The plagioclase which is predominant over alkali feldspar displays sericitic alteration. Quartz exhibits dominant subgrain rotation recrystallisation (Fig. 7B).

Sample MSI230176A

Sample MSI230176A is a granodioritic rock with a medium-grained (ca. 1 mm) texture (Fig. 6B). The sample consists essentially of plagioclase, quartz, amphibole and biotite (Fig. 7C–D). Accessory minerals include titanite and zircon. The plagioclase which is predominant displays sericitic alteration. Quartz exhibits amoeboid grains, partly consisting of several subgrains, which suggests combined grain boundary migration and subgrain rotation recrystallisation, respectively (Fig. 6B).

Sample SPN230377A

Sample SPN230377A is a schollen diatexite migmatite consisting of scattered, smaller blocks of lens-shape melanosome in a groundmass of heterogeneous, leucocratic neosome (Fig. 6C). At thin section scale only the neosome part can be observed, and mainly consists of K-feldspar, plagioclase, quartz, biotite and muscovite (Fig. 7E–D). K-feldspar is the most abundant phase and occurs as subhedral crystals and display perthitic texture (Fig. 7D). Quartz exhibits dominant bulging recrystallisation (Fig. 7D).

Sample MSI230137A

Sample MSI230137A is a diatexite migmatite with preserved paleosome of metagreywacke composition (Fig. 6D). At the thin section scale both the leucosome and the melanosome can be observed (Fig. 7G–H). The leucosome is composed of light-coloured minerals like K-feldspar, quartz and plagioclase as well as muscovite and chlorite. The darker melanosome (Fig. 6D) is essentially composed of biotite, muscovite and quartz.

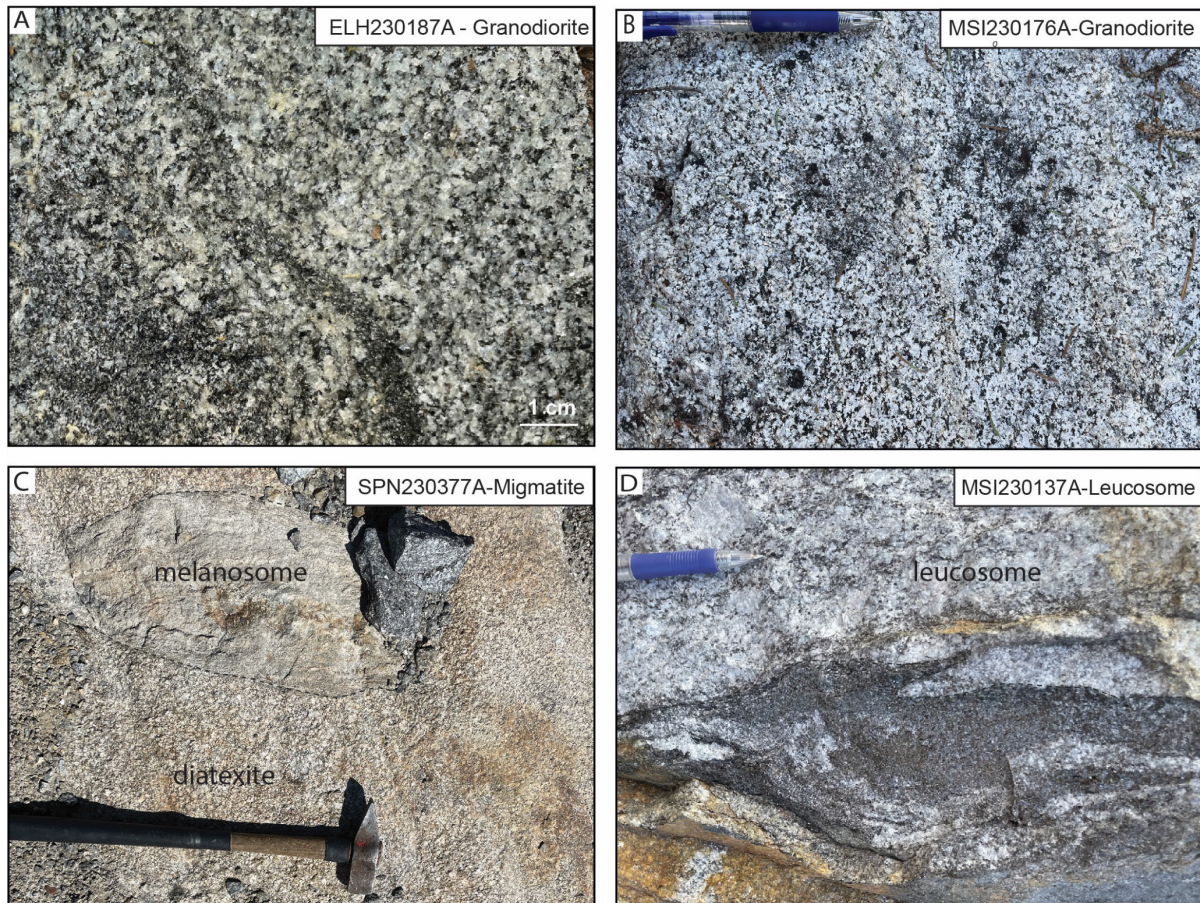


Figure 6. Outcrop and hand sample photos of granodioritic and migmatitic rock samples. **A.** Granodiorite with a medium to coarse-grained texture in the vicinity of the Järkvissle pegmatite, ELH230187A. **B.** Granodiorite with a medium-grained texture from the north of Härnösand area. **C.** Schollen diatexite migmatite consisting of scattered, smaller blocks of lens-shape melanosome in a groundmass of heterogeneous, leucocratic neosome. **D.** Diatexite migmatite with preserved paleosome of metagreywacke composition.

Sample SPN221204A

Sample SPN221204A is a leucocratic rock with a fine to medium grained texture and a well-developed tectonic foliation with a dip of 30 degrees (Fig. 8A–B). This foliation is marked by oriented and recrystallized bands of quartz, plagioclase, and alkali feldspar (mainly microcline) as well as oriented white mica and biotite (Fig. 9A–B). The mineralogical composition is mostly quartz and K-feldspar, and the total silica content is 74%. This rock has experienced a high degree of recrystallisation which makes it difficult to identify the protolith. Is it a meta-rhyolite? Muscovite, which is a common mineral in granite, occurs very rarely and only as an alteration product in rhyolite. In most granites the alkali feldspar is a soda-poor microcline or microcline-perthite while in most rhyolites, however, it is sanidine. In this sample there is a minor amount of white mica (1–2%) but it does not appear to be an alteration product (Fig. 9A–B). Moreover, most of the alkali feldspar (if not all) display a crosshatch twinning which is particularly common in microcline.

Sample MSI230033C

Sample MSI230033C is a leucocratic extrusive igneous rock with a porphyritic texture (Fig. 8B). The mineralogical composition is mostly quartz and K-feldspar with a total silica content of 70%. The groundmass is aphanitic microcrystalline (Fig. 9C–D). The phenocrysts include mainly quartz and K-feldspar, as well as muscovite and chlorite, most probably as a retrograde phase, and oxide (Fig. 9C–D). This rock presents a total sodium content of 3% and a total potassium content of 3 %, which in a TAS (total alkali silica) diagram falls within the dacite field.

Sample ELH210128A

Sample ELH210128A is a leucocratic extrusive or subvolcanic igneous rock with a porphyritic texture (Fig. 8C–D) which is exposed in contact with a foliated meta-granite via a vertical outcrop surface (Fig. 8C). The porphyritic rock is, in turn, crosscut by a narrow, irregular aplite-pegmatite dyke (Fig. 8C). The mineralogical composition is mostly quartz, plagioclase and K-feldspar and has a total silica content of 69%. The groundmass is aphanitic microcrystalline (Fig. 9E–F). The phenocrysts include quartz, K-feldspar, plagioclase, and biotite as well as chlorite, most probably as a retrograde phase (Fig. 9E–F). This rock presents a total sodium content of 5% and a total potassium content of 1.6 % which in a TAS (total alkali silica) diagram falls within the dacite field.

Sample ELH210117B

Sample ELH210117B is a foliated, fine to medium grained (ca. 0.2–2 mm), dark green-black amphibolite occurring as a dyke about 30 cm in width (Fig. 8E). This amphibolite dyke vertically crosscuts a foliated metagreywacke (S1 = 087/71).

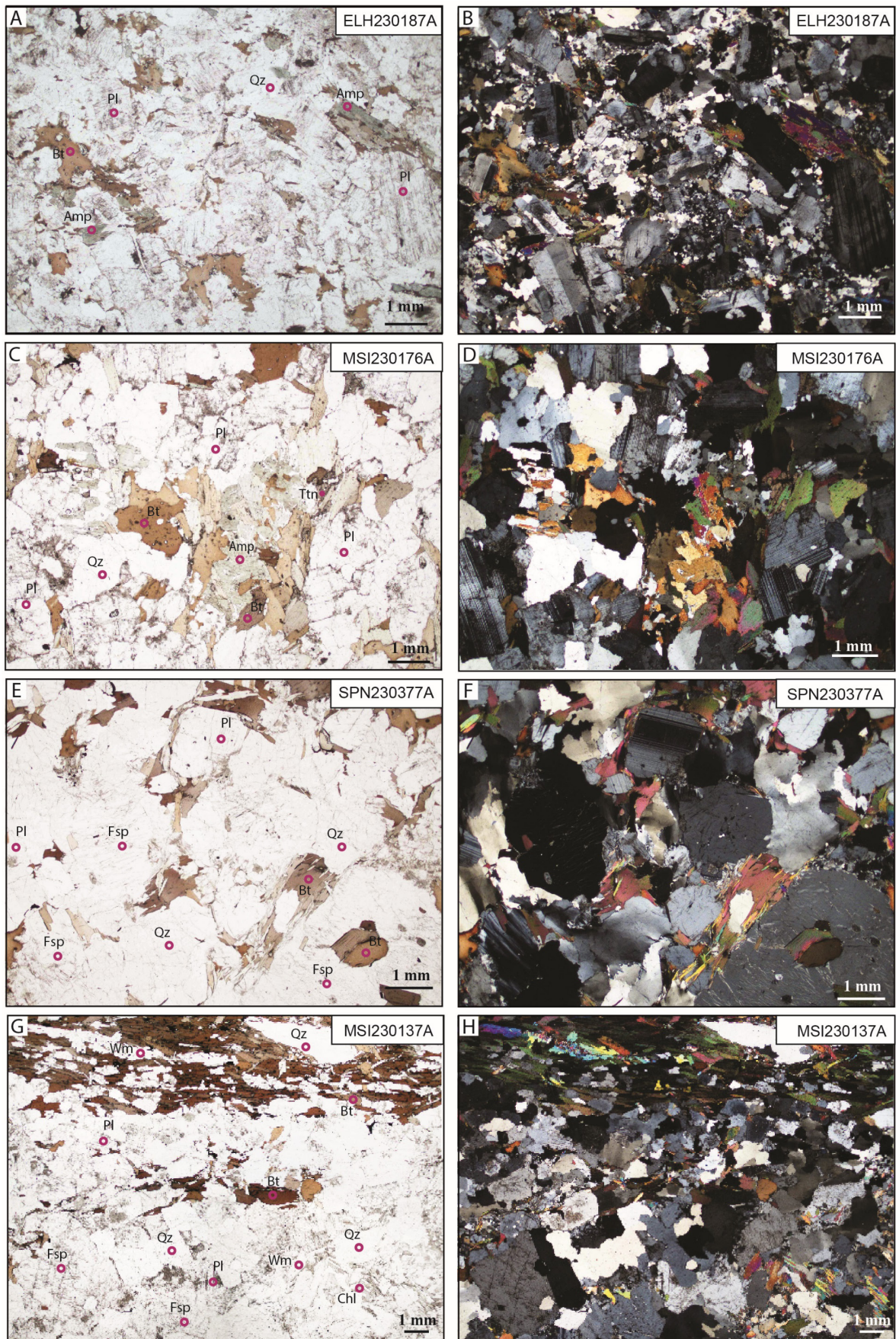


Figure 7. Optical microscope image in plane polarised light (left) and in cross-polarised light (right) of granodioritic and migmatitic samples in Fig. 6. Abbreviations: Amp = Amphibole, Bt = Biotite, Chl = Chlorite, Fsp = K-feldspar, Mc = Microcline, Pl = Plagioclase, Qz = Quartz, Ttn = Titanite, Wm = white mica.

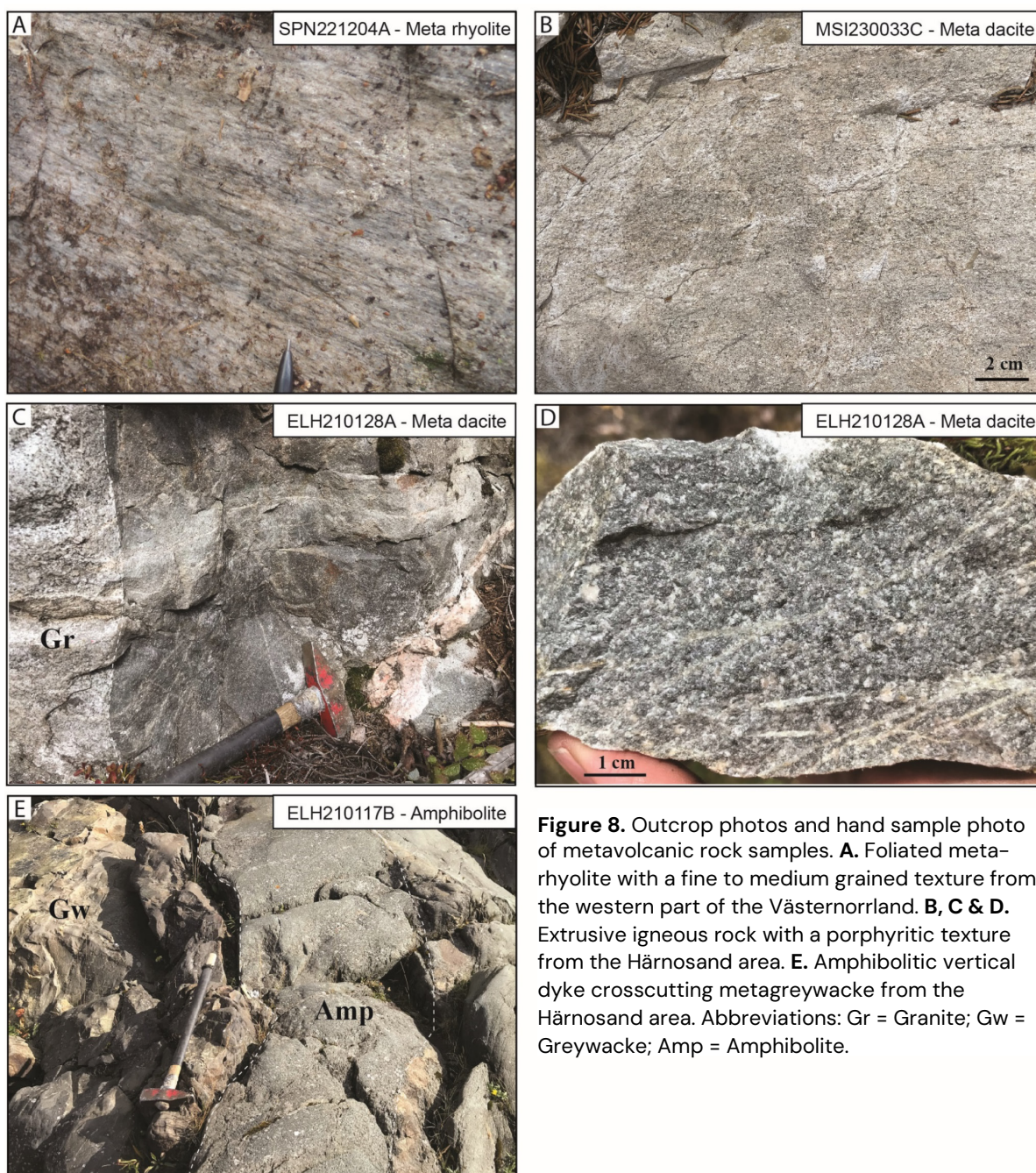


Figure 8. Outcrop photos and hand sample photo of metavolcanic rock samples. **A.** Foliated meta-rhyolite with a fine to medium grained texture from the western part of the Västernorrland. **B, C & D.** Extrusive igneous rock with a porphyritic texture from the Härnosand area. **E.** Amphibolitic vertical dyke crosscutting metagreywacke from the Härnosand area. Abbreviations: Gr = Granite; Gw = Greywacke; Amp = Amphibolite.

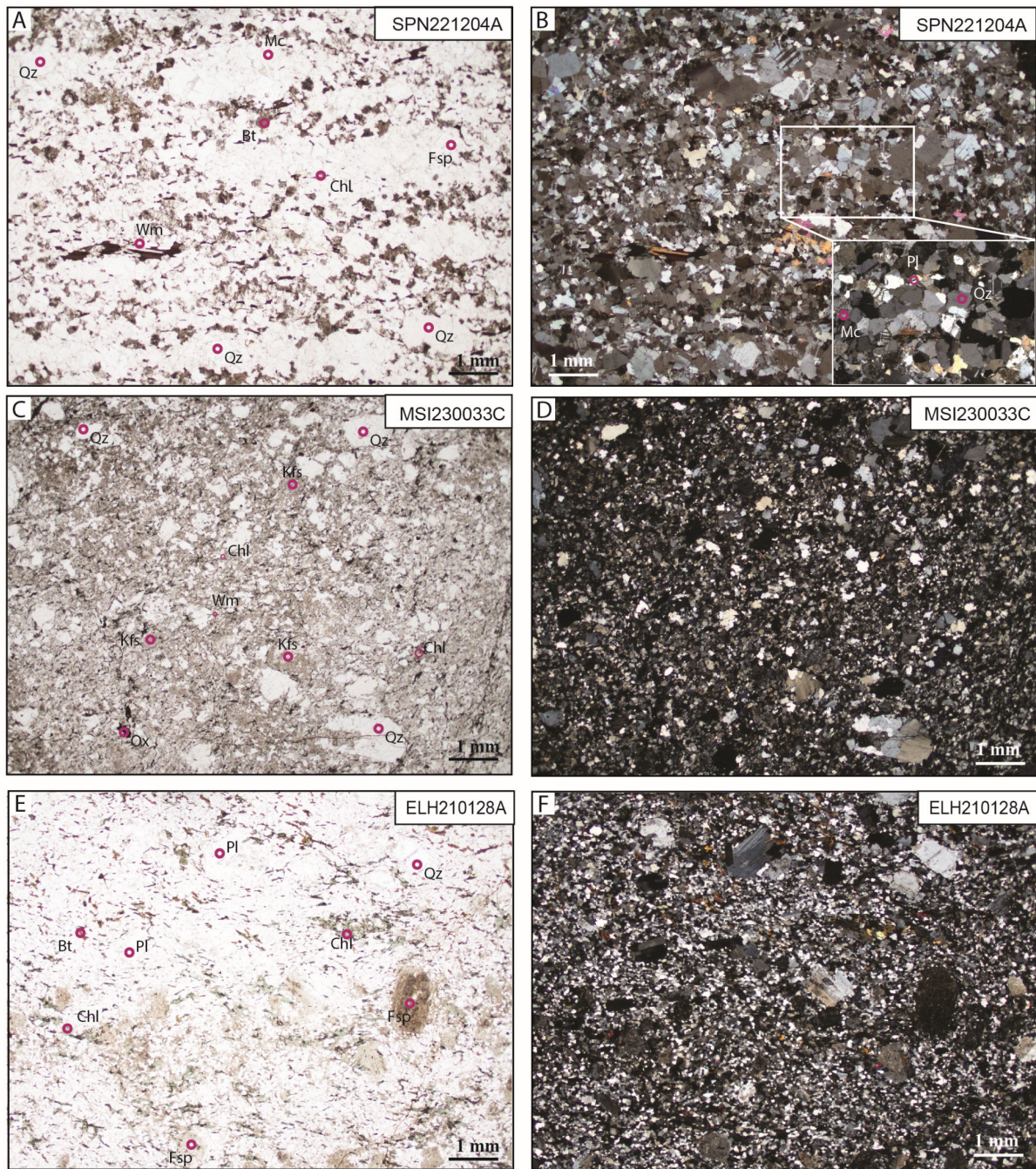


Figure 9. Optical microscope images in plane-polarised light (left) and in cross-polarised light (right) of metavolcanic rock samples in Fig. 8A–D. Abbreviations: Bt = biotite, Chl = Chlorite, Fsp = K-feldspar, Mc = Microcline, Ox = Oxide, Pl = Plagioclase, Qtz = Quartz, Wm = White mica.

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. Zircon crystals were randomly handpicked from heavy mineral concentrations, regardless of their size, clarity, colour, or morphology, with the goal of producing a final age distribution that accurately reflects the true distribution of zircon ages in each sample. Handpicked zircon 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 (CL) imaging using electron microscopy at the Swedish Museum of Natural History in Stockholm. Back-scattered electron (BSE) and CL images were used to visualize the internal structure of the zircon grains. Points for isotopic analysis were selected on several zircon grains to include all the texturally distinct domains identified (Fig. 10, 11, 13 and 15). High-spatial resolution secondary ion mass spectrometer (SIMS) analysis was done in April 2020 and 2024 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 ca. 6 nA O^{2-} primary ion beam was used, yielding spot sizes of ca. 10–20 μm . U/Pb ratios, elemental concentrations and Th/U ratios were calibrated relative to the Geostandards zircon 91500 reference, which has an age of ca. 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). Of the fifteen selected samples, 317 analyses were performed on 218 grains. All the results are summarised in Appendix 1, 2 and 3. 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.

ELH220115A (foliated biotite–muscovite granite with pegmatitic patches)

Zircon grains are subhedral to euhedral, elongated to rounded, and range in length from 50 to 200 μm . BSE and CL images reveal a core-rim zonation with rounded homogenous core surrounded by a larger euhedral rim which presents in some zircon grains a fine oscillatory magmatic zoning (Fig. 10A, Zr 02). The oscillatory zoning rim is sometimes truncated and overgrown by another narrow-unzoned rim (overgrowth) that may be metamorphic in origin (Fig. 10A, Zr 10, Zr 12 and Zr 16). Among the 20 analyses performed on this sample, 8 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 12A). The concordant analyses are spread along the Concordia between 1.8 Ga to 2.1 Ga. Individual apparent $^{207}Pb/^{206}Pb$ ages have been plotted in a KDE diagram (kernel density estimates; Vermeesch, 2012) to display the age distribution and its probability density (Fig. 12B). Two age peaks can be identified. If the oldest Paleoproterozoic dates (> 1.96 Ga) are excluded and interpreted as inherited, the older cluster (light brown) yields a weighted mean date of 1944 ± 10 Ma (MSWD = 5.8), and the younger (yellow) a weighted mean date of 1849 ± 10 Ma (MSWD = 2.6) (Fig. 12B). The youngest concordant population allows to calculate a Concordia date at 1856 ± 14 Ma (MSWD = 2.3) which is consistent with the weighted mean date calculated for the younger cluster. Th/U ratio, U content and textural emplacement of

the analysis spot of these two clusters do not show any systematic pattern which could help interpreting them. For example, an analysis spot located in core domain may be found in the two clusters (Fig. 12B).

ELH220082A (foliated biotite–muscovite granite)

Zircon grains are subhedral to euhedral, elongated to rounded, and range in length from 40 to 150 μm . BSE and CL images reveal a core-rim zonation with rounded core surrounded in most cases by a larger homogeneous and dark rim domains in CL (Fig. 10B, Zr 01, Zr 03, Zr 04 and Zr 14). In some zircon grains a fine oscillatory magmatic zoning could be distinguished (Fig. 10B, Zr 11). The rim is sometimes truncated and overgrown by another narrow rim (overgrowth) that displays corrosion features which could be related to a fluid-mediated alteration phase (Fig. 10B, Zr 03, Zr 04 and Zr 11). Some of the zircon have a CL-bright domain which yields older apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages (ca. 1.97 Ga) (Fig. 10B, Zr 01 and Zr 04). Analysis of such domain did not reveal any significant U enrichment (Appendix 1). Among the 24 analyses performed on this sample, 10 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 12C). The concordant analyses are spread along the Concordia between 1.85 Ga to 2.05 Ga and form two main clusters. The light brown ellipses represent the analysis spots of cores while the yellow ellipses represent the analysis spots from the dark rim domains in CL. The oldest Paleoproterozoic concordant dates obtained from the core are interpreted as inherited. The data obtained from the dark rim domain ($n = 8$) plots on a Discordia line with an upper intercept of $1867 \pm 4 \text{ Ma}$ (MSWD = 4.4) (Fig. 12C).

MSI220047A (foliated biotite–muscovite granite)

Zircon grains are subhedral to euhedral, mainly elongated, and range in length from 60 to 200 μm . BSE and CL images reveal a core-rim zonation for most of the zircon grains, with rounded homogeneous core surrounded by a larger euhedral rim which presents in some zircon grains a fine oscillatory magmatic zoning (Fig. 10C, Zr 08). The rim is sometimes truncated and overgrown by another narrow rim (overgrowth) that displays corrosion features which could be related to a fluid-mediated alteration phase (Fig. 10C, Zr 03, Zr 06, Zr 08, Zr 09). Some crystals display a relatively homogeneous CL and BSE domain without any clear core-rim zonation (Fig. 10C, Zr 02 and Zr 03). Among the 23 analyses performed on this sample, 10 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 12D). There are three older concordant dates which are interpreted as inherited, one is Mesoarchaeon and comes from the core of the zircon grain 12 and two are Paleoproterozoic and are represented as light brown ellipses on Figure 12D. They both come from the zircon grain (Zr 08) which displays a very well defined oscillatory magmatic zoning (Fig. 10C). Unfortunately, the narrow overgrowth of this grain could not be analysed. The rest of the concordant data set ($n = 10$; yellow ellipses) plots on a discordia line with an upper intercept of $1862 \pm 3 \text{ Ma}$ (MSWD = 0.36) (Fig. 12D).

SPN210189A (muscovite–biotite granite)

Zircon grains are subhedral to euhedral, elongated to rounded, and range in length from 60 to 120 μm . BSE and CL images reveal a core-rim zonation for most of the zircon grains, with rounded to euhedral core. Some of the zircon grains display a metamict texture with intense fracturing. A fine oscillatory magmatic zoning can also be distinguished in a few grains (Fig. 10D, Zr 08). The core/rim domain is often overgrown by narrow to thick homogeneous dark rim domains in CL (Fig. 10D, Zr 08, Zr 10, Zr 11, Zr 12 and Zr 13) that might correspond to a metamorphic stage. Among the 21 analyses performed on this sample, 12 were discordant

(degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 12E). The concordant analyses are spread along the Concordia between 1.8 Ga to 2.15 Ga. Individual apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages have been plotted in a KDE diagram (kernel density estimates; Vermeesch, 2012) to display the age distribution and its probability density (Fig. 12F). Several age peaks can be identified (youngest at ca. 1.85 Ga) but none of them is dominant and allows to calculate a Concordia date. The homogenous dark rim domains in CL yield strongly discordant data.

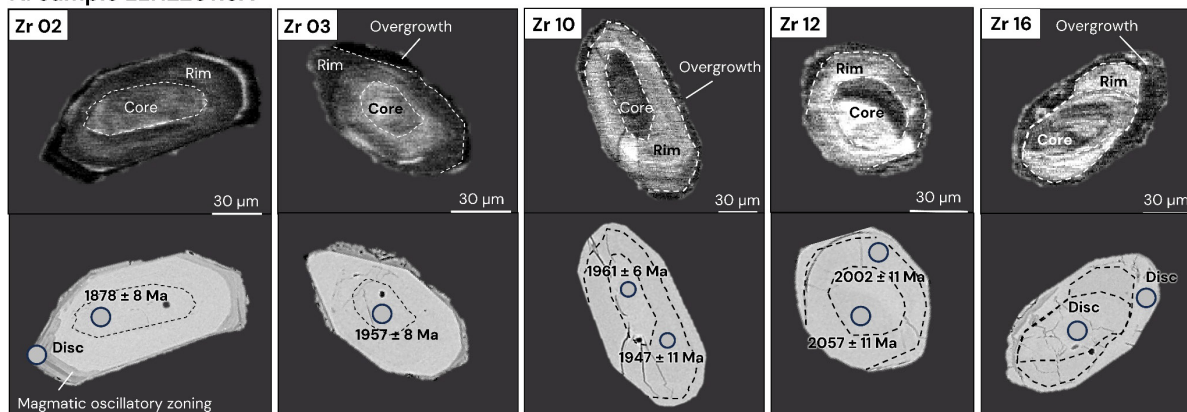
MSI230042A (muscovite $\pm$ biotite granite)

Zircon grains are subhedral to euhedral, mainly rounded, and range in length from 20 to 150 μm . BSE and CL images reveal a core-rim zonation with rounded core surrounded in most cases by a larger homogeneous and dark rim domains in CL (Fig. 11A, Zr 03, Zr 07, and Zr 09). The rim is sometimes truncated and overgrown by another thick and darker rim (overgrowth) that displays corrosion features which could be related to a fluid-mediated alteration phase (Fig. 11A, Zr 03, Zr 07, and Zr 09). Some of the zircon have a CL-bright domain which yields older apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages (ca. 1.97 Ga) (Fig. 11A, Zr 01 and Zr 04). Among the 22 analyses performed on this sample, 17 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 12G). The concordant analyses are spread along the Concordia between 1.85 Ga to 2.05 Ga. The light brown ellipses represent the analysis spot from the core while the yellow ellipses represent the analysis spot from the dark rim domains in CL. However, there is only one concordant analysis from the rim, therefore this textural relationship between younger age and the rim should be taken with caution. The oldest Paleoproterozoic concordant dates obtained from the core are interpreted as inherited. The data obtained from the dark rim domain, if we include the two rim-spots that have a degree of concordance of 98% ($n = 3$), plots on a Discordia line with an upper intercept of $1848 \pm 6 \text{ Ma}$ (MSWD = 0.96) (Fig. 12G).

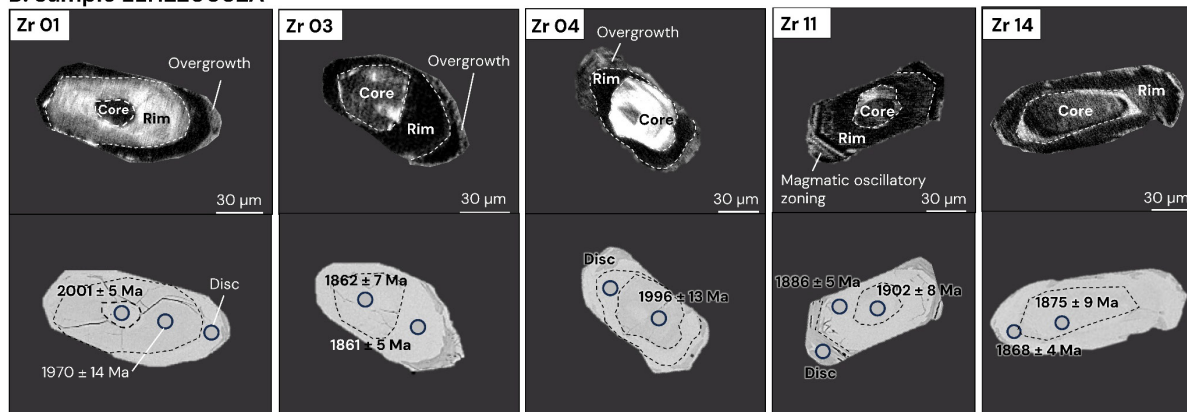
ELH230145B (microgranite dyke crosscutting migmatite and metagranitoid)

Zircon grains are subhedral to euhedral, elongated to rounded, and range in length from 50 to 150 μm . BSE and CL images reveal a subtle core-rim zonation for most of the zircon grains, with rounded to euhedral core. Some of the zircon grains display a metamict texture with intense fracturing. A fine oscillatory magmatic zoning usually associated with a bright CL domain can also be distinguished in a few grains (Fig. 11B, Zr 06). In this specific case the rim is overgrown by narrow to thick homogenous dark rim domains in CL (Fig. 11B, Zr 06). Among the 20 analyses performed on this sample, 5 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 12H). The concordant analyses are spread along the Concordia between 1.5 Ga to 2.05 Ga, however only 3 spots are younger than 1.9 Ga and represented as purple ellipses on Figure 12H. Two of these younger dates come from the same zircon grain (Fig. 11B, Zr 06), characterised by a well-defined oscillatory magmatic zoning and a bright CL domain, and allows calculating a Concordia date at $1674 \pm 11 \text{ Ma}$ (MSWD = 0.059). Older individual apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages have been plotted in a KDE diagram (kernel density estimates; Vermeesch, 2012) to display the age distribution and its probability density (Fig. 12I). Two age peaks can be identified, the older cluster yields a weighted mean date of $2693 \pm 49 \text{ Ma}$ ($n = 3$; MSWD = 11), and the younger one a weighted mean date of $1996 \pm 41 \text{ Ma}$ ($n = 9$; MSWD = 79) (Fig. 12I).

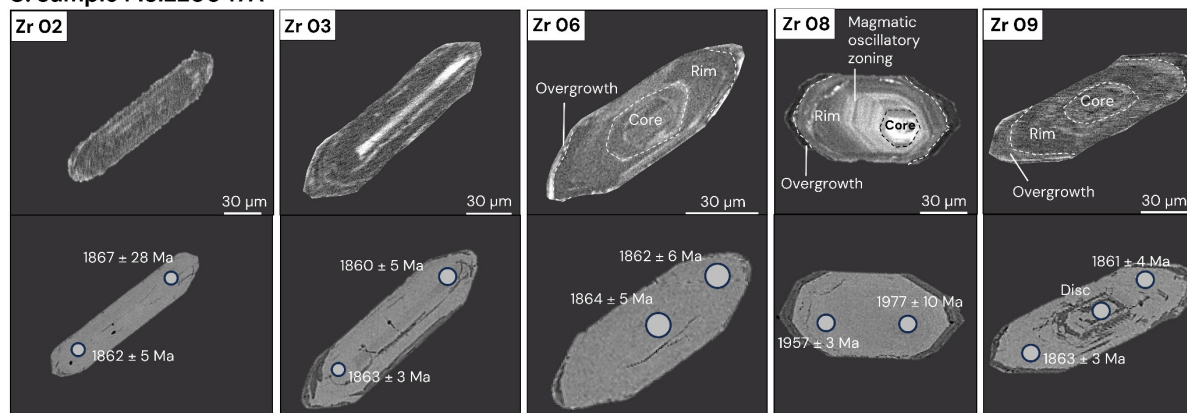
A. Sample ELH220115A



B. Sample ELH220082A



C. Sample MSI220047A



D. Sample SPN210189A

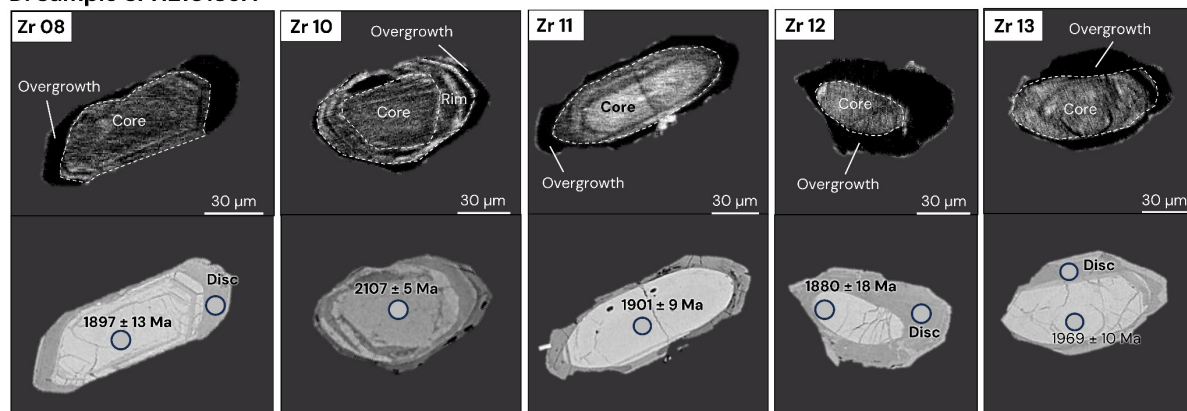
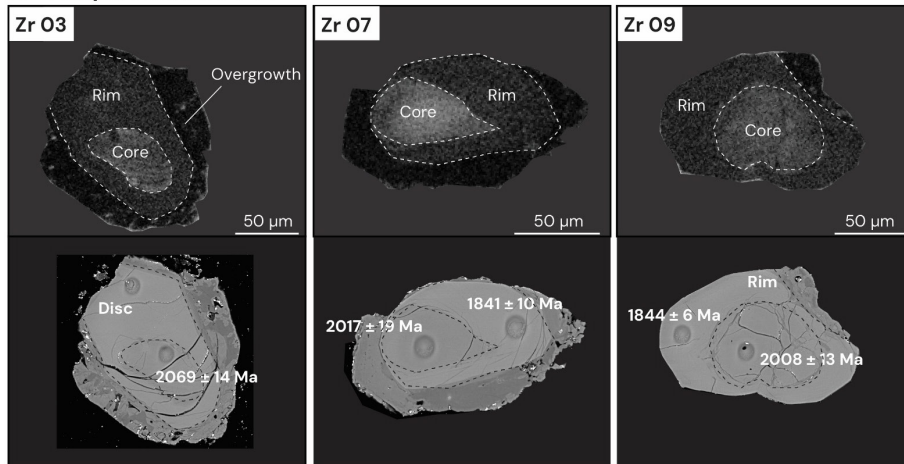
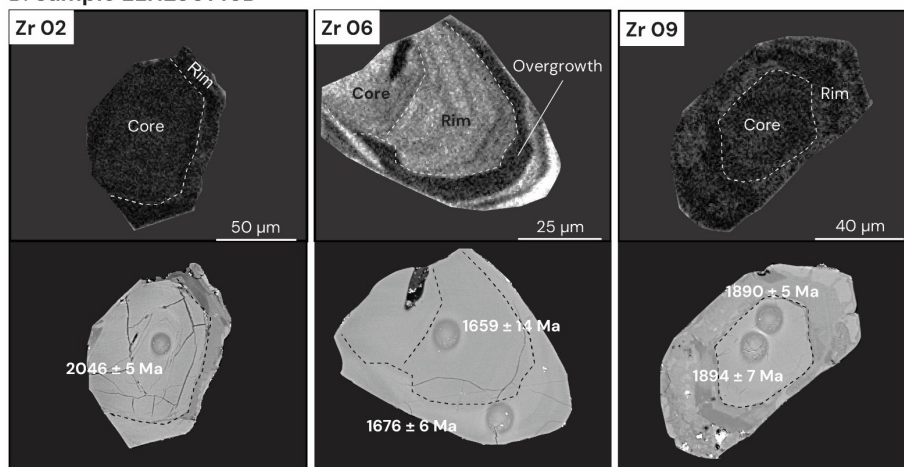


Figure 10. BSE and CL images of zircon grains in granitic samples described in Figs. 3A–D and 4.

A. Sample MSI230042A



B. Sample ELH230145B



C. Sample SPN230513A

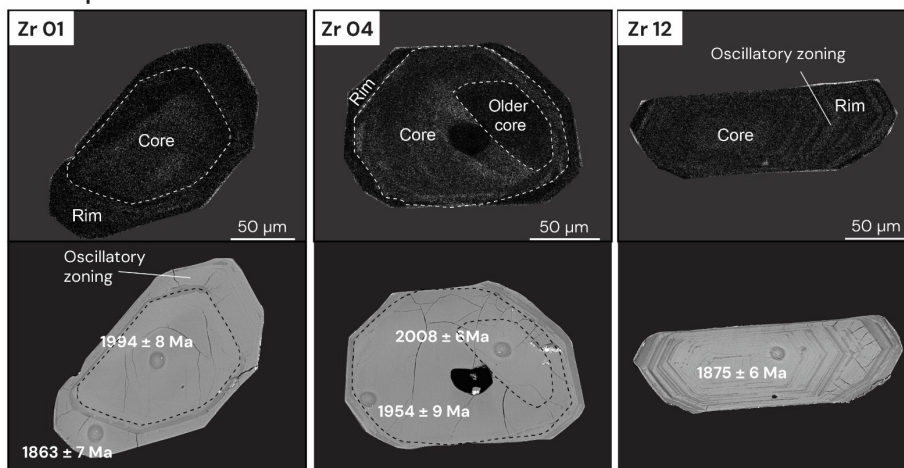
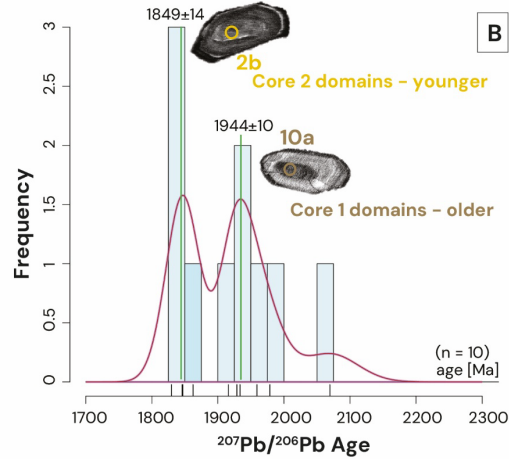
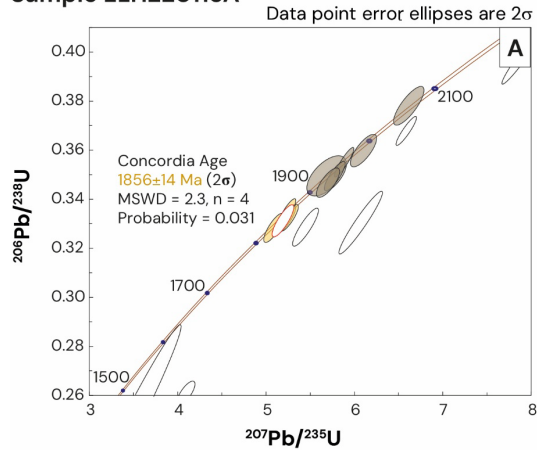
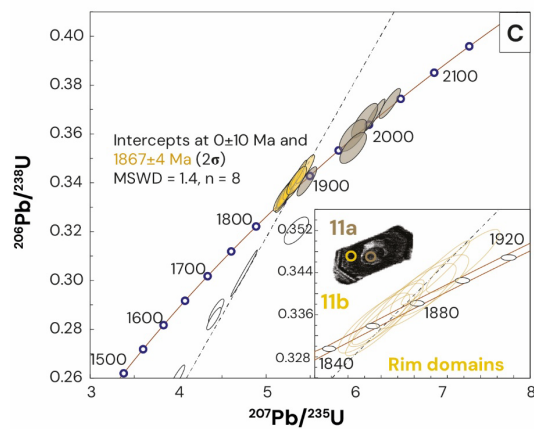


Figure 11. BSE and CL images of zircon grains in granitic samples described in Figs. 3E–G and 5.

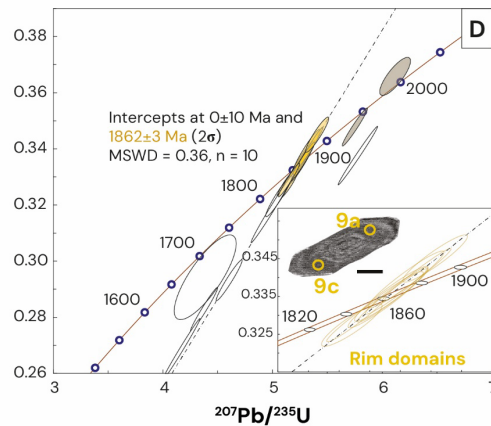
Sample ELH220115A



Sample ELH220082A



Sample MSI220047A



Sample SPN210189A

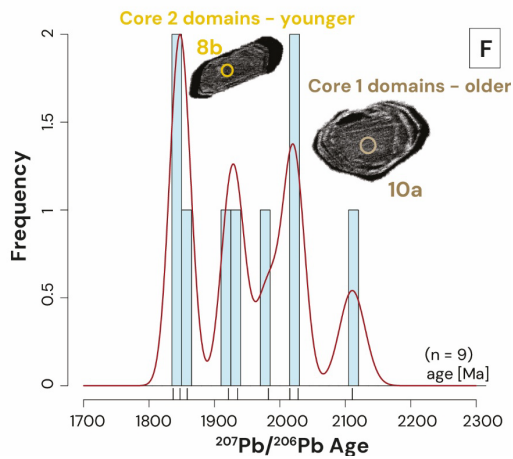
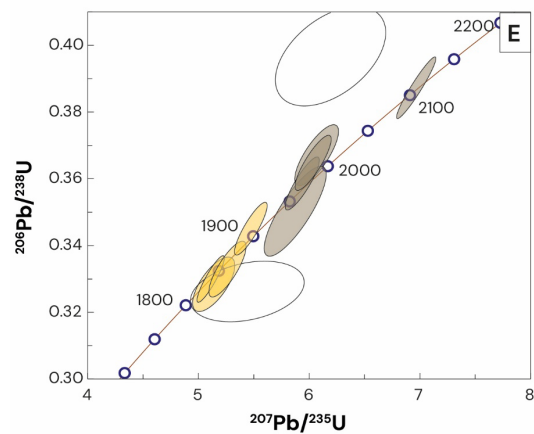
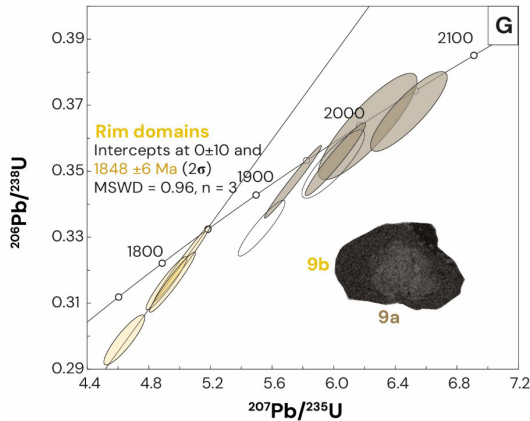
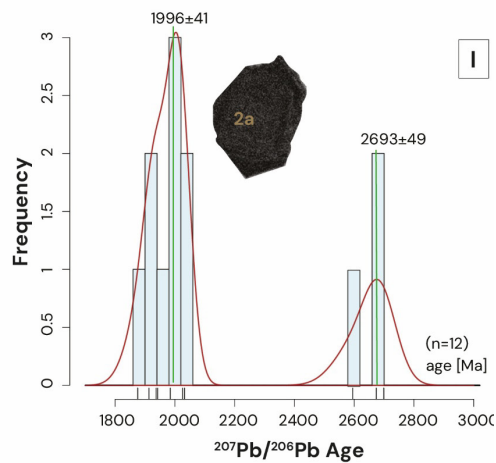
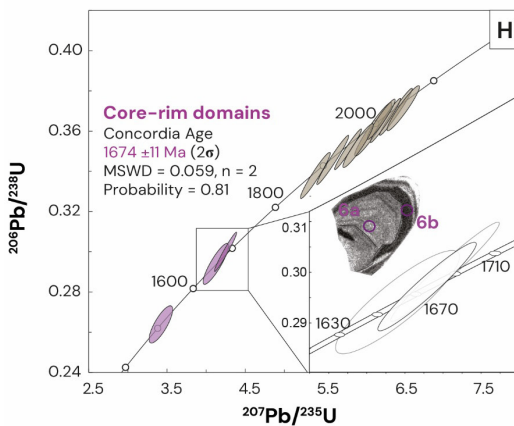


Figure 12. U-Pb Concordia and weighted mean age diagram of granitic samples. Yellow colour shows younger domains and brown shows older domains. The figure continues on the next page.

Sample MSI230042A



Sample ELH230145B



Sample SPN230513A

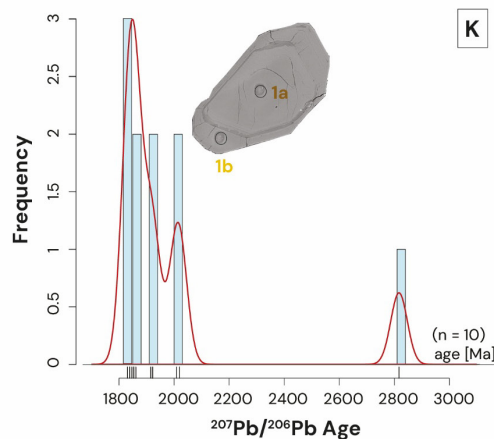
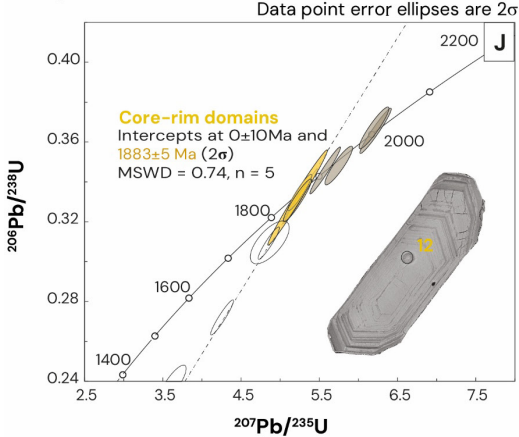


Figure 12. (continued) U-Pb Concordia and weighted mean age diagram of granitic samples.

SPN230513A (weakly foliated biotite granodiorite)

Zircon grains are mostly euhedral and elongated, and range in length from 90 to 300 μm . BSE and CL images reveal a core-rim zonation for most of the zircon grains. Some of the grains show a rounded core which usually yields older apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages surrounded by a larger euhedral rim domain (Fig. 11C, Zr 01 and Zr 04). Most of the grains display a well-defined oscillatory magmatic zoning in the core and rim domains (Fig. 11C, Zr 12). Among the 22 analyses performed on this sample, 12 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 12J). The concordant analyses are spread along the Concordia between 1.85 Ga to 2.8 Ga. Individual apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages

have been plotted in a KDE diagram (kernel density estimates; Vermeesch, 2012) to display the age distribution and its probability density (Fig. 12K). Two age peaks can be identified, the oldest one, represented by only one analysis at ca. 2.86 Ga is interpreted as inherited dates and the younger one which is predominant ($n = 5$) plots on a discordia line with an upper intercept of 1883 ± 5 Ma (MSWD = 0.74) (Fig. 12J).

ELH230187A (foliated granodiorite)

Zircon grains are mostly euhedral, rounded to elongated, and range in length from 70 to 250 μm . BSE and CL images reveal a core-rim zonation for most of the zircon grains, with brighter CL euhedral core surrounded by larger euhedral rim which presents a fine oscillatory magmatic zoning (Fig. 13A, Zr 05 and Zr 09). Some of the zircon have a CL-bright domain with rounded homogenous core which yields older apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages (Fig. 13A, Zr 11) and presents higher Th/U ratio (Appendix 2). Rarely, the rim is truncated and overgrown by another narrow rim (overgrowth) that displays corrosion features which could be related to a fluid-mediated alteration phase (Fig. 13, Zr 11). Among the 23 analyses performed on this sample, 10 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 14A). There are two older concordant dates which are interpreted as inherited and represented as light brown ellipses on Figure 14A. The rest of the concordant data set is distributed between core ($n = 9$) and rim domains ($n = 2$) and are represented as yellow ellipses on Figure 14A. All taken together these 11 concordant data allows to calculate a concordia date at 1869 ± 3 Ma (MSWD = 1.4).

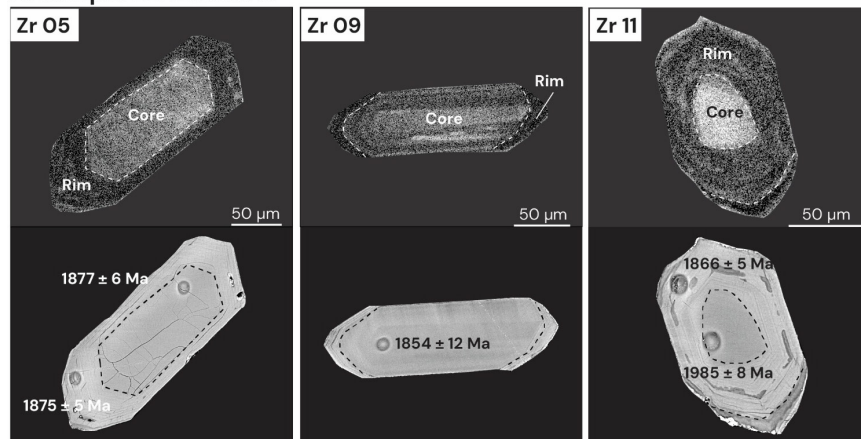
MSI230176A (granodiorite)

Zircon grains are mostly euhedral and elongated, and range in length from 80 to 300 μm . BSE and CL images reveal a core-rim zonation with a well-defined oscillatory magmatic zoning in the core and rim domains (Fig. 13B, Zr 01, Zr 08 and Zr 10). Rarely, the rim is truncated and overgrown by another narrow and homogeneous rim (overgrowth) (Fig. 13B, Zr 08 and Zr 10). Among the 20 analyses performed on this sample, 7 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 14B). The 13 remaining concordant analyses located either in the core or in the rim of the zircon grain have been plotted all together and allow to calculate a concordia date at 1866 ± 7 Ma (MSWD = 1.6).

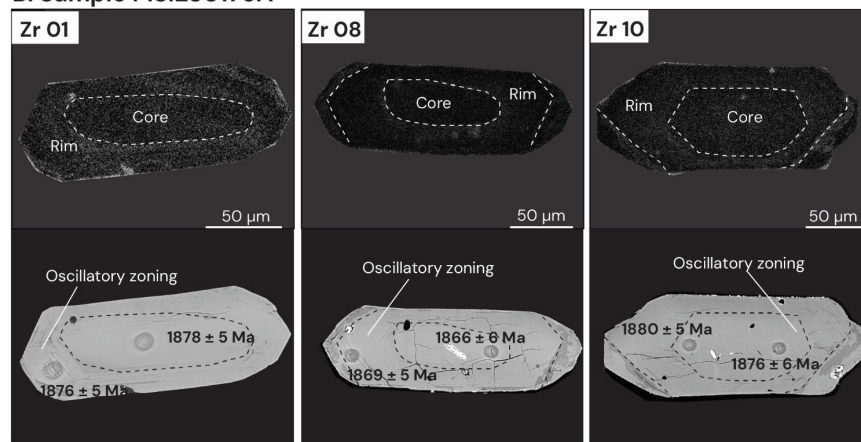
SPN230377A (diatexite migmatite)

Zircon grains are subhedral to euhedral, elongated to rounded, and range in length from 80 to 200 μm . CL and BSE images reveal a core-rim zonation for most of the zircon grains. The cores are rounded to embayed and surrounded by a larger rim which is also rounded in most cases (Fig. 13C, Zr 10, and Zr 14) and can display fine oscillatory magmatic zoning. The rim seems to be associated mainly with brighter CL domain. The rim and sometimes even the core are truncated and overgrown by a thick and homogeneous darker rim (overgrowth) (Fig. 13C, Zr 02, Zr 10 and Zr 14) which is most probably of metamorphic origin. Among the 20 analyses performed on this sample, all of them were concordant and have been plotted in Figure 14C. The concordant analyses are spread along the Concordia between 1.85 Ga to 3.0 Ga. Individual apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages for spot analyses located in the core of zircon grains have been plotted in a KDE diagram (kernel density estimates; Vermeesch, 2012) to display the age distribution and its probability density (Fig. 14D). One predominant age peak can be identified ($n = 9$) at ca. 1980 Ma, the older Individual apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages are widely spread and are interpreted as inherited dates. Six analyses have been performed on the overgrowth of zircon grains (Appendix 2, Fig. 13, Zr 02, Zr 10 and Zr 14) and they yield a concordant date of 1862 ± 6 Ma (MSWD = 0.68) (Fig. 14C).

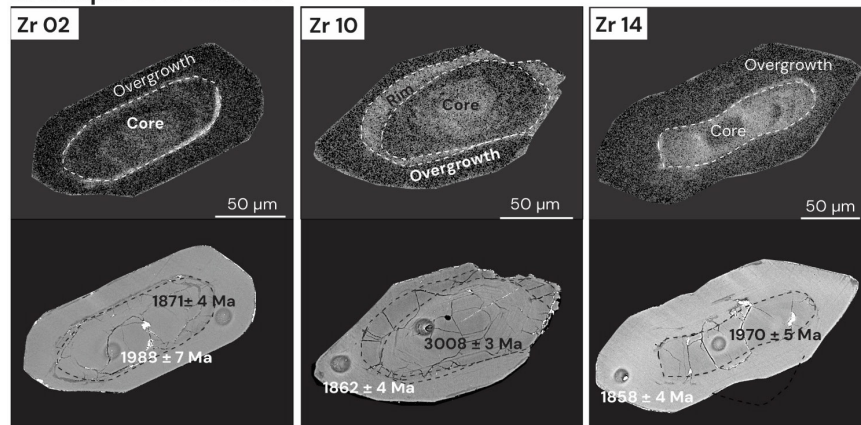
A. Sample ELH230187A



B. Sample MSI230176A



C. Sample SPN230377A



D. Sample MSI230137A

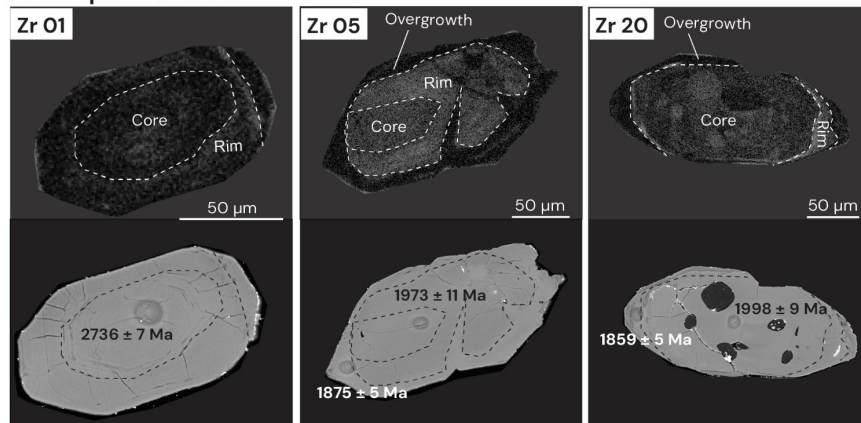
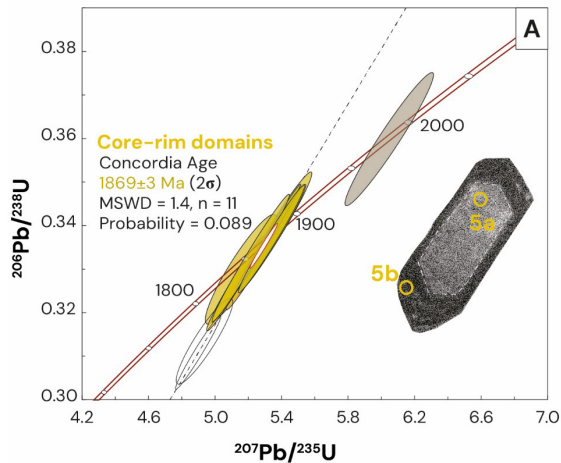
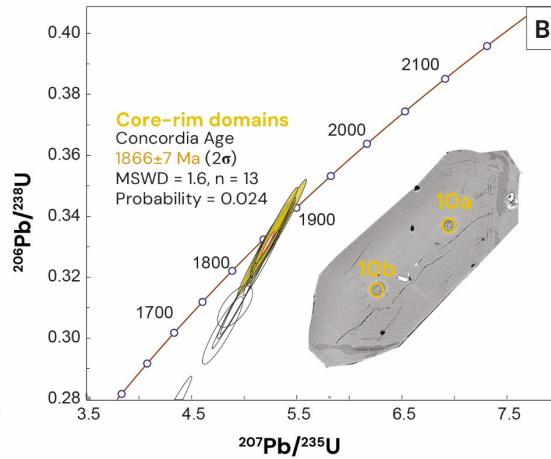


Figure 13. BSE and CL images of zircon grains in granodioritic and migmatitic samples described in Figs. 6 and 7.

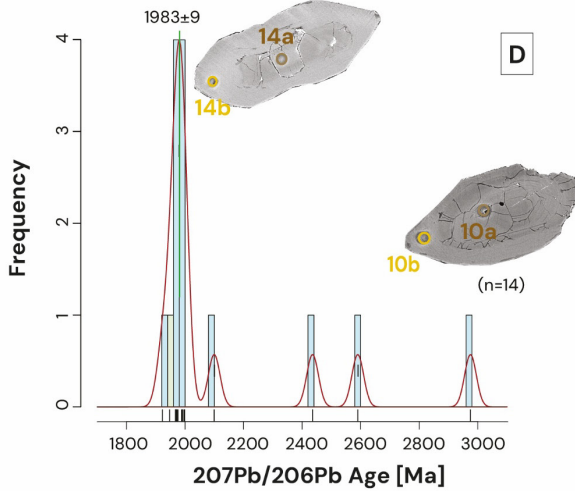
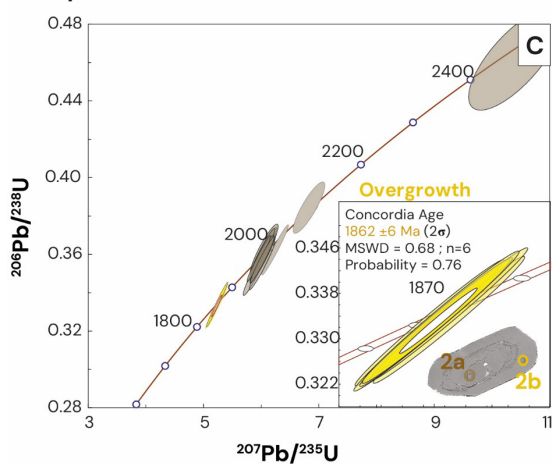
Sample ELH230187A



Sample MSI230176A



Sample SPN230377A



Sample MSI230137A

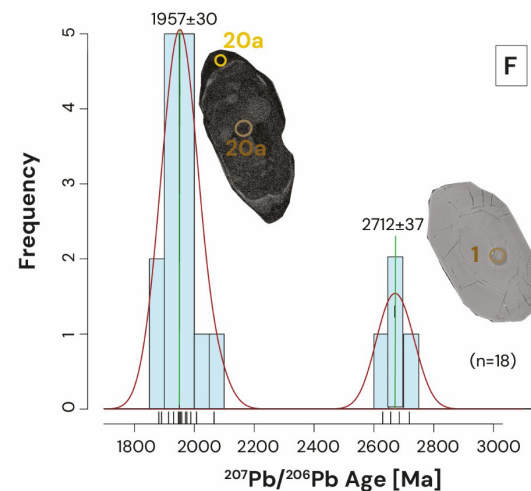
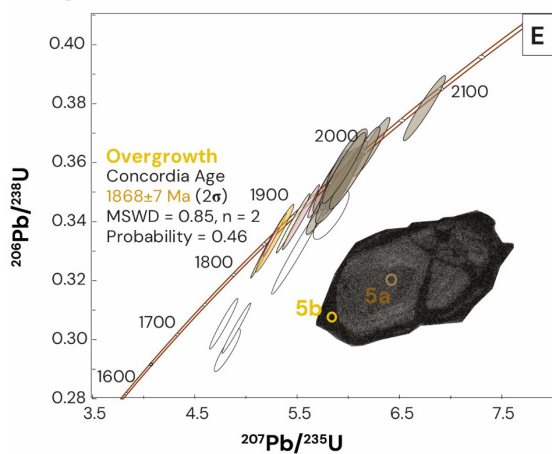


Figure 14. U-Pb Concordia and weighted mean age diagram of granodioritic and migmatitic sample. Yellow colour shows younger domains and brown shows older domains.

MSI230137A (diatexite migmatite)

Zircon grains are subhedral to euhedral, elongated to rounded, and range in length from 50 to 250 μm . CL and BSE images reveal a core-rim zonation. The cores are rounded to embayed and surrounded by a larger rim which is also rounded in most cases (Fig. 13D, Zr 01, Zr 05, and Zr 20). The rim seems to be associated mainly with brighter CL domain. The rim and sometimes even the core are truncated and overgrown by a thick and homogeneous darker rim (overgrowth) (Fig. 13D, Zr 5 and Zr 20) which is most probably of metamorphic origin. Among the 28 analyses performed on this sample, 8 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 14E). The concordant analyses are spread along the Concordia between 1.86 Ga to 2.7 Ga. Individual apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages for spot analyses located in the core of zircon grains have been plotted in a KDE diagram (kernel density estimates; Vermeesch, 2012) to display the age distribution and its probability density (Fig. 14F). Two age peaks can be identified, the older cluster yields a weighted mean date of 2712 ± 37 Ma ($n = 4$), and the younger one a weighted mean date of 1957 ± 30 Ma ($n = 14$) (Fig. 14F). Older individuals apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages are interpreted as inherited dates. Two analyses have been performed on the overgrowth of zircon grains (Appendix 2 and Fig. 13D, Zr 05 and Zr 20) and yield a concordant date of 1868 ± 7 Ma (MSWD = 0.85) (Fig. 14E).

SPN221204A (meta-rhyolite)

Analyses have been performed with a spot size of 20 μm . Zircon grains are subhedral to euhedral, elongated to rounded, and range in length from 60 to 200 μm . CL images reveal a core-rim zonation for most of the zircon grains which is barely visible on BSE images. The cores are rounded to elongated and surrounded by a larger euhedral rim. A fine oscillatory magmatic zoning can also be distinguished in a few grains (Fig. 15A, Zr 17). Among the 19 analyses performed on this sample, 5 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 16A). The oldest concordant date is Mesoarchaean (ca. 2.8 Ga) and interpreted as inherited (Appendix 3, Table 1, Zr 18a). The twelve concordant analyses from the core allow to calculate a concordia date of 1873 ± 2 Ma (MSWD of concordance and equivalence = 1.3) (Fig. 16A). The remaining concordant analysis comes from the rim of zircon 4 (Fig. 15A) and yields an apparent $^{207}\text{Pb}/^{206}\text{Pb}$ age of 1878 ± 5 Ma (yellow ellipse in the concordia diagram).

MSI230033C (meta-dacite to rhyolite)

Zircon grains are subhedral to euhedral, elongated to rounded, and range in length from 50 to 200 μm . CL and BSE images reveal a core-rim zonation for most of the zircon grains. The cores are rounded to embayed and surrounded by a larger rim which is also rounded in most cases (Fig. 15B, Zr 11, Zr 13 and Zr 17). Grain domains defined by CL images do not show any systematic pattern which could help interpreting them, brighter domains can correspond to a core as well as a rim domain. The rim is truncated and overgrown by another thick and in most cases darker rim (overgrowth) that displays cracks features (Fig. 15B, Zr 11, Zr 13 and Zr 17). Among the 28 analyses performed on this sample, 10 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 16B). Individual apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages have been plotted in a KDE diagram (kernel density estimates; Vermeesch, 2012) to display the age distribution and its probability density (Fig. 16C). Two age peaks can be identified, the older cluster ($n = 3$) at ca. 2.7 Ga is interpreted as inherited dates and the younger one which is predominant ($n = 13$) plots on a discordia line with an upper intercept of 1978 ± 8 Ma (MSWD = 3.3) (Fig. 16B).

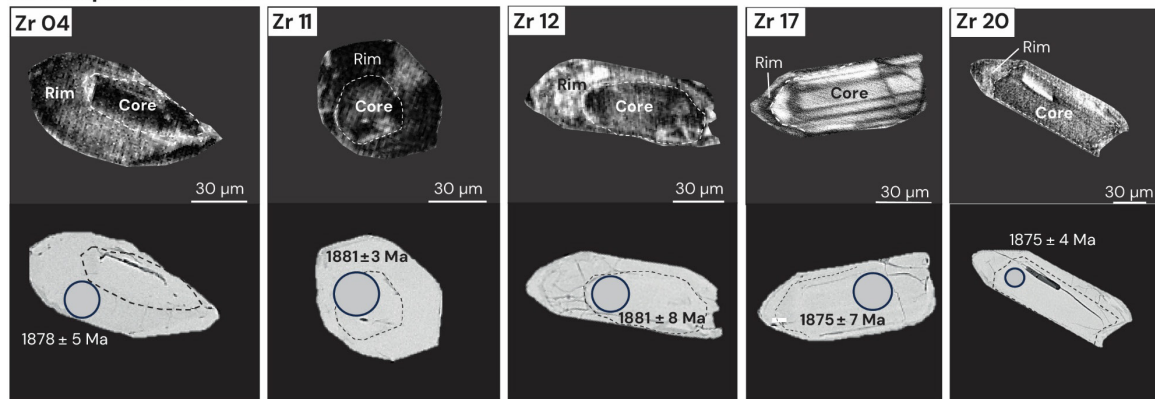
ELH210128A (porphyritic meta-dacite)

Zircon grains are euhedral, mainly elongated, and range in length from 70 to 200 μm . BSE and CL images reveal a core-rim zonation. Most of the zircon grains display a well-defined oscillatory magmatic zoning (Fig. 15C, Zr 06, Zr 10 and Zr 13) especially on CL images. Among the 19 analyses performed on this sample, 15 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 16D). The oldest concordant, Paleoproterozoic date (ca. 1.97 Ga) is interpreted as inherited (Appendix 3, Table 3, Zr 11, light brown ellipse in Fig. 16D). The remaining concordant analyses (Core/Rim domain) plot roughly on a discordia line with an upper intercept of $1869 \pm 8 \text{ Ma}$ (MSWD = 0.31) (Fig. 16D, yellow ellipse).

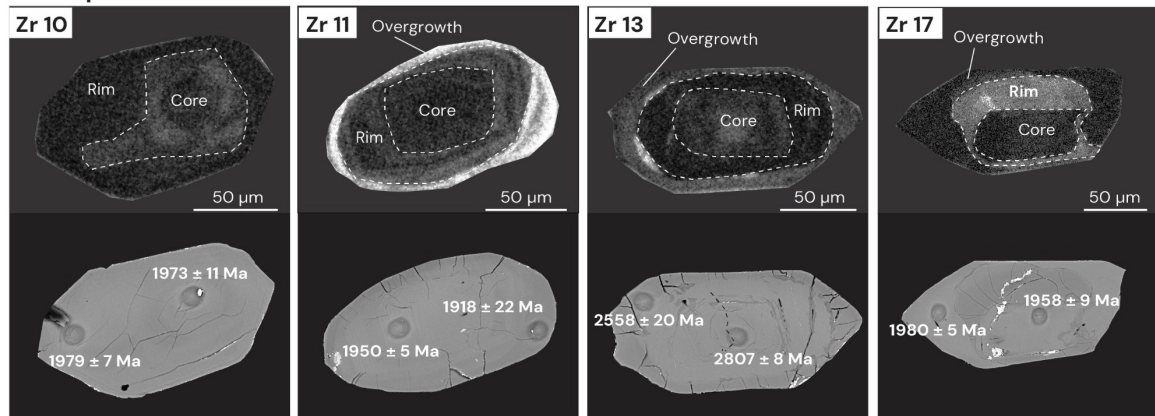
ELH210117B (amphibolite dyke crosscutting metagreywacke)

Only three zircon grains were analysed, and they all show different features and zoning patterns. Zircon 1 displays a clear core-rim zonation with a rounded core surrounded by a larger euhedral rim that exhibits oscillatory zoning (Fig. 15D, Zr 01). In the zircon 3, the core is much more homogeneous and there is no oscillatory zoning preserved or visible (Fig. 15D, Zr 03). A common characteristic for these three grains is that the core/rim domain is overgrown by a narrow homogenous dark rim domains in CL (Fig. 15D, Zr 01 and Zr 03) that might correspond to a metamorphic or a fluid-mediated alteration phase. Among the 8 analyses performed on this sample, 6 were discordant (degree of concordance lower than 99% and greater than 101%) and have been plotted in white (Fig. 16E). The only two concordant analyses (yellow ellipse in Fig. 16E) come from the homogeneous core domain of zircon 3 (Fig. 15) and allow calculate a Concordia date of $1854 \pm 5 \text{ Ma}$ (MSWD of concordance and equivalence = 2) (Fig. 16E).

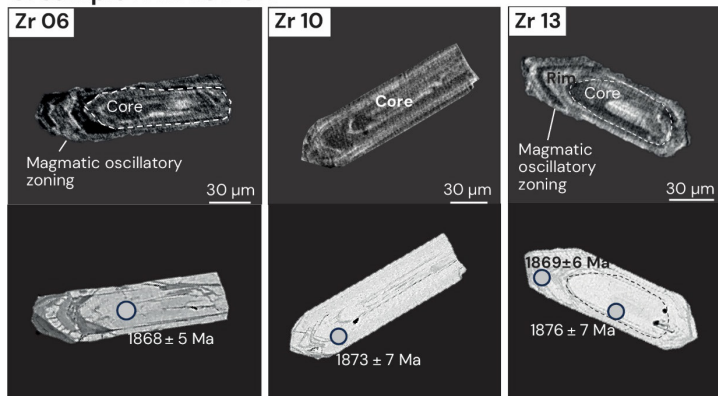
A. Sample SPN221204



B. Sample MSI230033C



C. Sample ELH210128A



D. Sample ELH210017B

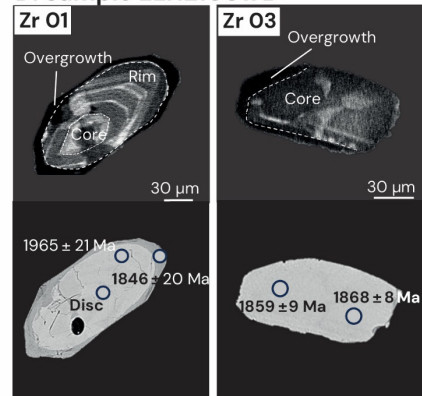
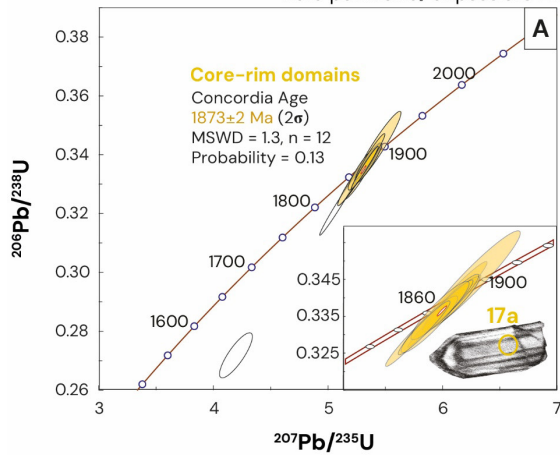
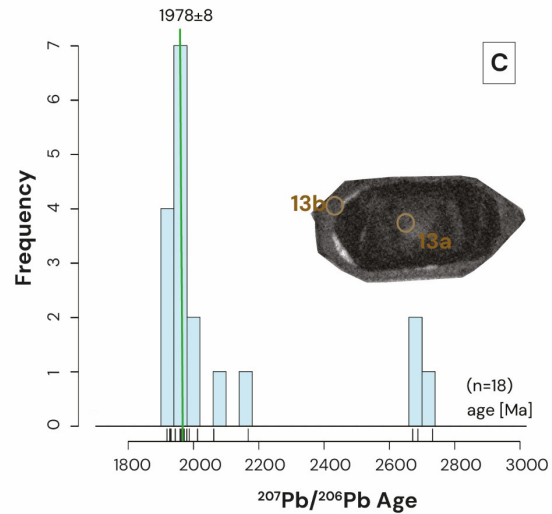
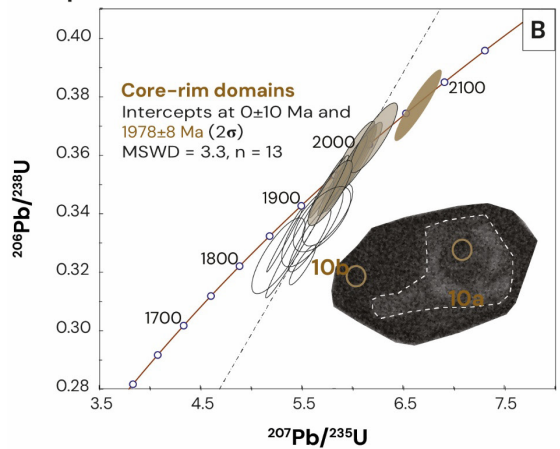


Figure 15. BSE and CL images of zircon grains in the metavolcanic rock samples described in Figs. 8 and 9.

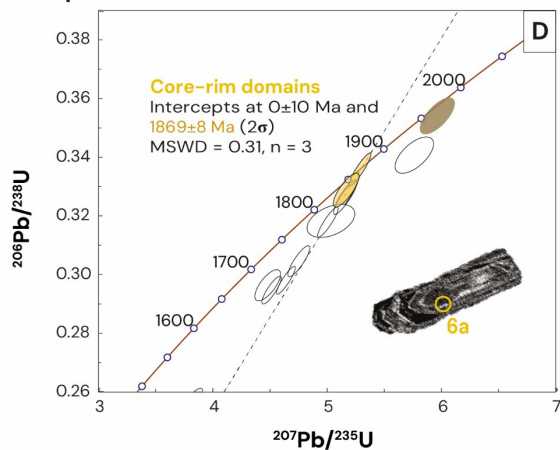
Sample SPN221204A Data point error ellipses are 2σ



Sample MSI230033C



Sample ELH210128A



Sample ELH210117B

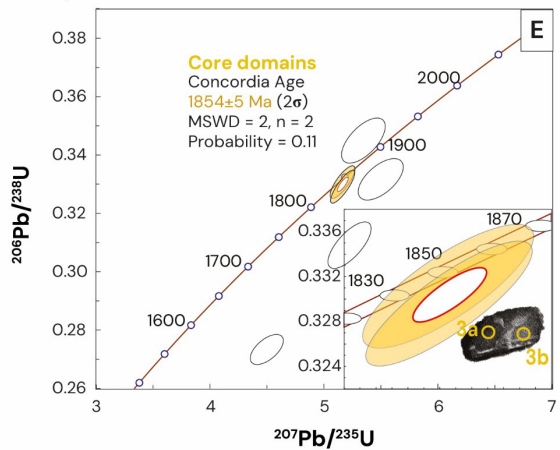


Figure 16. U-Pb Concordia diagram of the metavolcanic rock samples. Yellow colour shows younger domains and brown shows older domains.

Discussion and conclusion

The age dataset obtained from separated zircon coming from foliated and undeformed granitoids, migmatitic rock as well as metavolcanic rocks are used to define the timing and the origin of the various intrusive suites that have formed in the Västernorrland area and to discuss the likely geodynamic evolution of the southern part of the Bothnia–Skellefteå lithotectonic unit at around 1.97–1.85 Ga. The existing U-Pb zircon ages from this area have been plotted in Figure 2. They all have been interpreted as magmatic ages and no metamorphic age has been deciphered from U-Pb zircon dating so far.

Felsic plutonic rocks emplaced at 1.87–1.85 Ga

Four of the granitic samples (ELH22015A, ELH22082A, SPN210189A and MSI230042A) display a similar age signature with two distinct clusters, one at around 1.99–1.94 Ga and usually more spread along Concordia, and one younger at around 1.87–1.85 Ga. The oldest plutonic suite recognised in this area has been emplaced between 1.95 and 1.93 Ga, while the siliciclastic metasedimentary rocks corresponding to the host rocks of those intrusive rocks have been deposited during the time span 1.96 (or older)–1.86 Ga. Therefore, the oldest date cluster cannot be interpreted directly as the emplacement age and more likely could be in some cases related to inherited ages derived from incorporated source material.

For sample ELH2200115A which is a weakly foliated equigranular granite with pegmatitic parts located west of the Järkvissle pegmatite field and near a major NW/SE deformation zone (Fig. 2), the oldest weighted mean date of 1944 ± 10 Ma was obtained from a zircon core and from the rim of zircon grains which display oscillatory zoning. The 1.94 Ga signature is interpreted as inherited source material. The youngest concordant population of this sample was obtained from the core of the zircon grain that displayed alteration features and yields a concordant date of 1856 ± 14 Ma which is interpreted as the granite forming event, synchronous with regional D2-related metamorphism and migmatisation. To confirm this interpretation and clearly identify the magmatic age of this granitic rock more data would be needed.

Sample ELH220082A is also weakly foliated and located in the vicinity of the Järkvissle pegmatites, but in this case an older age cluster is more spread out along Concordia and gives a weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ date of ca. 1.99 Ga (Appendix 1). This age signature is marginally older than the inherited signature in the sample ELH2200115A and does not correspond to any existing plutonic suite ages, although it is broadly consistent with the ca. 1.98 Ga age determined for the felsic metavolcanic rock from Dala-Gårdbergsmyran (sample MSI230033C, see sub-section “Felsic volcanic activity at 1.98 Ga and 1.87 Ga”). Moreover, most of the older apparent $^{207}\text{Pb}/^{206}\text{Pb}$ ages come from core domains which are mainly rounded and thus are likely inherited. If the older cluster is interpreted as an inherited age signature, the dark rim domain of the zircon grains that yield an upper intercept age of 1867 ± 4 Ma could be interpreted as the magmatic age of this granitic rock that could be linked to the plutonic suites emplaced at 1.87–1.84 Ga (Fig. 2). This dark rim domain is quite homogeneous and does not display a clear oscillatory zoning in most of the cases except in the zircon grain 11 (Fig. 15B), therefore this interpretation should be taken with caution. In this sample, most of the zircons display an additional grain domain that overprints the dark rim domain and may be metamorphic in origin. Unfortunately, the spot analyses from this specific domain only yield discordant data.

Sample SPN210189A is a foliated biotite-muscovite granite from the Härnösand area and shows a similar age pattern to the previous sample. Indeed, an older cluster is more spread out along Concordia, giving a weighted mean date of about 1.99 Ga (Appendix 1). This older core domain is interpreted to be inherited. In this sample none of the age clusters gave a concordant age but a

younger cluster that yields a weighted mean date of 1871 ± 11 Ma overlaps with the ca. 1.87–1.86 Ga granite crystallisation ages from Järkvissle area and represents a best estimate for the magmatic age of this granite.

For granite sample MSI230042A, none of the age clusters yield a concordant date and the older cluster is quite spread along the Concordia line (Fig. 12G). The dark rim domain of the zircon grains that yield an upper intercept age of 1848 ± 6 Ma could be interpreted as the age of metamorphism/ deformation. To confirm this interpretation and identify the magmatic age of this granitic rock more data would be needed from the rim domain.

Sample ELH230145B is a microgranite dyke that crosscuts both migmatitic metasedimentary rock and a foliated metagranitoid. Two age peaks can be identified; the older cluster yields a weighted mean date of 2693 ± 49 Ma and the younger one a weighted mean date of 1996 ± 41 Ma. While none of the individual analyses yield a concordant age and no proper interpretation can be made on the igneous crystallisation age of this granite, these older age signatures may represent xenocrystic zircons within the dyke and reflect older inherited igneous material. Moreover, one zircon grain that gave a Concordia date at **1674 ± 11 Ma has been identified. This date does not correspond to any known geological event in the area.** To better understand those results, more data acquisition would be needed and especially in-situ zircon dating which gives better a constraint on the textural setting of zircon grains.

Felsic plutonic rock emplaced at 1.88–1.86 Ga

One granitic sample and three granodioritic samples show clear emplacement ages between 1.88–1.86 Ga (MSI220047A, MSI230176A, ELH230187A and SPN230513A). In sample SPN230513A, zircon grains display very well defined oscillatory magmatic zoning, and the only old date (2.6 Ga) is interpreted as inherited, the rest of the concordant data plots on a Discordia line with an upper intercept of 1883 ± 5 Ma and this is interpreted as the igneous crystallisation age of the granodiorite. In sample MSI220047A, which comes from the vicinity of the Järkvissle pegmatite field, three grains yielded older ages which are interpreted as inherited, the rest of the concordant dataset gave an upper intercept age of 1862 ± 3 Ma which is interpreted as the igneous crystallisation age of the granite. MSI230176A and ELH230187A have a granodioritic composition and show both a similar age signature, in MSI230176A, all the concordant analyses located either in the core or in the rim of the zircon grain have been plotted all together and allow to calculate a concordia date at 1866 ± 7 Ma which is interpreted as the igneous crystallisation age of the granodiorite. In sample ELH230187A, apart from two analyses which are interpreted as inherited, the rest of the concordant data allows for the calculation of a Concordia date at 1860 ± 3 Ma, and this date is also interpreted as the igneous crystallisation age of the granodiorite.

Felsic volcanic activity at 1.98 Ga and 1.87 Ga

The age dataset obtained from the metavolcanic rocks is easier to interpret. Two felsic metavolcanic samples yield a similar age interpreted as the magmatic age of those rocks; sample SPN221204A yields a concordant and robust age of 1873 ± 2 Ma, while sample ELH210128A yields an upper intercept age of 1869 ± 8 Ma. These two samples were historically mapped as granitoid (Fig. 2), but their magmatic ages at ca. 1.87 Ga suggests they formed during a phase of syn-orogenic felsic volcanic activity that occurred between 1.91–1.87 Ga as part of the buildup of the Bothnian supergroup (Skyttä et al. 2020). Sample MSI230033C, which is also a felsic metavolcanic rock, yields an upper intercept age of 1978 ± 8 Ma which is interpreted as the igneous crystallisation age of the rock. This result suggests that volcanic activity in the southern Bothnian Basin occurred before even 1.96 Ga, which is the oldest felsic volcanic activity recorded

in the area (Skyttä et al. 2020). The newly acquired older ca. 1.98 Ga age for the volcanic rock also provides a maximum depositional age for siliciclastic metasedimentary rocks that enclose the volcanic interbed in this part of the basin. The dated amphibolite dyke sample ELH210117B yielded a concordant age of 1854 ± 5 Ma, which is also interpreted as a magmatic age and is younger than the ca. 1.87 Ga ages for the dated felsic volcanic rock samples. The age of the amphibolite tentatively suggests subordinate mafic magmatic activity occurred during D2-related metamorphism and migmatization from ca. 1.87–1.85 Ga (cf. Skyttä et al. 2020). The ca. 1.85 Ga age result for the amphibolite should be considered with caution, however, as it relies only on two analyses which come from the same zircon grain.

Migmatization event at ca. 1.86 Ga

The two dated diatexite migmatite samples (SPN230377A and MSI230137A) show similar age signatures. Archaean inherited zircon grains occur in both samples with a more abundant cluster in sample MSI230137A giving a date of ca. 2.71 Ga. The most predominant age cluster at ca. 1.98 Ga comes from the core-domain of inherited zircon grains. In both samples, zircon grains display an overgrowth domain which yields concordant ages of 1862 ± 6 Ma and 1868 ± 7 Ma, respectively. This age of 1.86 Ga is interpreted to constrain the timing of high temperature migmatization.

Acknowledgments

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Appendix 1. U–Pb zircon data obtained in granitic samples

Appendix 1, Table 1. U–Pb zircon data obtained in sample **ELH220115A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	core	154	155	376	0.41	0.114	0.488	5.232	0.869	0.332	0.719	0.83	1858	7	1848	12	1869	9	99
2a	rim	2917	1528	10634	0.13	0.101	1.447	3.355	8.332	0.241	8.206	0.98	1494	67	1390	103	1645	27	91
2b	core	183	156	454	0.34	0.115	0.448	5.268	0.808	0.333	0.672	0.83	1864	7	1851	11	1878	8	99
3a	core	170	171	392	0.43	0.120	0.452	5.784	0.835	0.350	0.701	0.84	1944	7	1932	12	1957	8	99
5a	core	249	399	322	1.34	0.201	0.342	13.693	1.351	0.494	1.307	0.97	2729	13	2589	28	2834	6	96
6a	core	135	212	314	0.67	0.113	0.539	5.095	0.917	0.328	0.742	0.81	1835	8	1831	12	1840	10	100
7a	overgrowth	1313	139	19641	0.00	0.058	0.728	0.502	2.174	0.063	2.048	0.94	413	7	395	8	517	16	80
7b	core	237	2	636	0.00	0.114	0.384	5.244	0.771	0.335	0.669	0.87	1860	7	1862	11	1858	7	100
8a	core	25	56	49	1.17	0.118	1.290	5.692	1.607	0.350	0.958	0.60	1930	14	1933	16	1928	23	100
10a	core	351	244	821	0.30	0.120	0.312	5.891	0.761	0.355	0.694	0.91	1960	7	1959	12	1961	6	100
10b	rim	89	37	220	0.16	0.119	0.617	5.708	0.939	0.347	0.707	0.75	1933	8	1920	12	1947	11	99
11a	core	155	219	361	0.65	0.120	0.517	5.447	1.095	0.329	0.965	0.88	1892	9	1832	15	1960	9	97
12a	rim	123	85	284	0.28	0.123	0.647	6.111	0.993	0.360	0.753	0.76	1992	9	1982	13	2002	11	99
12b	core	84	67	180	0.38	0.127	0.635	6.623	1.062	0.378	0.851	0.80	2062	9	2068	15	2057	11	100
13a	core	135	109	441	0.21	0.114	0.672	4.095	1.009	0.261	0.752	0.75	1653	8	1495	10	1861	12	89
14a	core	575	170	1216	0.15	0.144	0.298	7.896	1.177	0.398	1.138	0.97	2219	11	2160	21	2275	5	98
15a	overgrowth	291	170	1057	0.01	0.114	0.614	3.869	1.867	0.247	1.763	0.94	1607	15	1421	23	1861	11	86
15b	core	49	28	85	0.35	0.184	1.234	11.392	1.705	0.448	1.177	0.69	2556	16	2387	24	2693	20	95
16a	core	147	99	370	0.23	0.133	0.497	6.071	1.658	0.330	1.581	0.95	1986	15	1841	25	2141	9	93
16b	overgrowth	436	183	1040	0.03	0.130	0.290	6.587	0.720	0.368	0.659	0.92	2058	6	2019	11	2096	5	98

Appendix 1, Table 2. U–Pb zircon data obtained in sample **ELH220082A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1 σ	²⁰⁷ Pb/ ²³⁵ U	1 σ	²⁰⁶ Pb/ ²³⁸ U	1 σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	$\pm\sigma$	²⁰⁶ Pb/ ²³⁸ U	$\pm\sigma$	²⁰⁷ Pb/ ²⁰⁶ Pb	$\pm\sigma$	
1a	core	482	618	1010	0.615	0.123	0.271	6.241	0.778	0.368	0.729	0.94	2010	7	2019	13	2001	5	100
1b	rim	61	67	133	0.515	0.121	0.759	5.995	1.064	0.359	0.745	0.70	1975	9	1980	13	1970	14	100
1c	overgrowth	716	474	2177	0.109	0.112	0.416	4.440	0.808	0.288	0.693	0.86	1720	7	1630	10	1831	8	94
3a	core	239	248	572	0.444	0.114	0.398	5.282	0.808	0.336	0.703	0.87	1866	7	1870	11	1862	7	100
3b	rim	367	38	969	0.041	0.114	0.301	5.288	0.777	0.337	0.717	0.92	1867	7	1872	12	1861	5	100
4a	rim	760	225	1888	0.119	0.114	0.216	5.509	0.738	0.350	0.705	0.96	1902	6	1936	12	1865	4	102
4b	core	76	138	156	0.915	0.123	0.728	5.996	1.033	0.354	0.733	0.71	1975	9	1955	12	1996	13	99
6a	core	262	335	538	0.632	0.125	0.376	6.414	0.775	0.373	0.677	0.87	2034	7	2041	12	2027	7	100
7a	core	101	163	202	0.835	0.122	0.612	6.126	1.002	0.366	0.793	0.79	1994	9	2008	14	1979	11	101
7b	rim	360	317	1114	0.082	0.113	0.373	4.413	0.757	0.284	0.658	0.87	1715	6	1614	9	1841	7	93
8a	rim	1525	77	4496	0.019	0.114	0.162	4.756	1.304	0.303	1.294	0.99	1777	11	1706	19	1861	3	95
8b	core	231	88	322	0.159	0.103	0.696	8.903	6.930	0.625	6.895	0.99	2328	65	3128	173	1686	13	138
9a	core	85	25	227	0.142	0.121	0.787	5.351	1.062	0.320	0.713	0.67	1877	9	1792	11	1973	14	95
9b	rim	276	45	703	0.07	0.115	0.344	5.497	0.759	0.346	0.677	0.89	1900	7	1917	11	1882	6	101
9c	overgrowth	819	456	5268	0.089	0.092	0.645	1.768	1.408	0.139	1.252	0.89	1034	9	839	10	1472	12	70
10a	rim	209	3	559	0.005	0.114	0.399	5.249	0.778	0.335	0.667	0.86	1861	7	1863	11	1858	7	100
10b	core	19	54	43	0.776	0.119	2.233	5.506	2.484	0.336	1.089	0.44	1901	22	1867	18	1939	40	98
11a	rim	1085	97	3742	0.013	0.111	0.372	3.989	0.954	0.260	0.878	0.92	1632	8	1489	12	1821	7	90
11b	rim	459	37	1220	0.037	0.114	0.304	5.266	0.750	0.335	0.686	0.91	1863	6	1861	11	1866	5	100
11c	core	220	230	517	0.458	0.116	0.424	5.470	0.835	0.341	0.719	0.86	1896	7	1890	12	1902	8	100
13a	core	53	72	91	0.839	0.151	0.830	8.853	1.188	0.425	0.849	0.72	2323	11	2282	16	2360	14	98
13b	rim	196	10	514	0.018	0.114	0.474	5.366	0.855	0.340	0.712	0.83	1879	7	1886	12	1872	9	100
14a	core	155	96	381	0.256	0.115	0.478	5.404	0.828	0.342	0.676	0.82	1886	7	1895	11	1875	9	101
14b	rim	914	219	2330	0.09	0.114	0.195	5.420	0.721	0.344	0.694	0.96	1888	6	1907	11	1868	4	101

Appendix 1, Table 3. U–Pb zircon data obtained in sample **MSI220047A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	rim	276	1168	792	0.2539	0.114	0.265	4.609	1.047	0.293	1.013	0.97	1751	9	1658	15	1864	5	94
1b	core	488	5684	1713	0.207	0.115	2.132	3.830	3.790	0.243	3.133	0.83	1599	31	1400	40	1872	38	85
2a	rim	304	317	732	0.4344	0.114	0.290	5.271	0.933	0.336	0.887	0.95	1864	8	1866	14	1862	5	100
2b	rim	380	394	943	0.3014	0.114	1.556	5.283	1.824	0.336	0.951	0.52	1866	16	1866	15	1867	28	100
3a	rim	173	84	428	0.1886	0.114	0.288	5.413	0.797	0.345	0.743	0.93	1887	7	1911	12	1860	5	101
3b	rim	382	115	989	0.1176	0.114	0.193	5.287	0.784	0.337	0.760	0.97	1867	7	1870	12	1863	3	100
4a	core	684	539	2019	0.2997	0.112	0.232	4.380	1.163	0.283	1.140	0.98	1709	10	1606	16	1837	4	93
5a	rim	506	1352	1267	0.35	0.114	0.188	5.156	0.768	0.329	0.744	0.97	1845	7	1833	12	1859	3	99
6a	core	232	81	601	0.1462	0.114	0.287	5.252	0.954	0.334	0.910	0.95	1861	8	1859	15	1864	5	100
6b	rim	329	292	814	0.4142	0.114	0.343	5.142	0.786	0.327	0.708	0.90	1843	7	1826	11	1862	6	99
7b	rim	528	297	2380	0.1022	0.104	1.171	2.816	1.595	0.195	1.082	0.68	1360	12	1151	11	1705	22	80
7c	rim	329	242	810	0.2864	0.114	0.280	5.319	0.948	0.340	0.906	0.96	1872	8	1884	15	1858	5	101
8a	rim	368	70	925	0.0796	0.120	0.191	5.758	0.820	0.348	0.797	0.97	1940	7	1924	13	1957	3	99
8b	core	95	79	211	0.3703	0.121	0.549	6.125	0.935	0.366	0.757	0.81	1994	8	2010	13	1977	10	101
9a	rim	1107	11696	3054	0.08	0.114	0.204	5.004	1.589	0.319	1.575	0.99	1820	14	1784	25	1861	4	98
9b	core	870	1982	1760	1.1916	0.124	0.157	5.786	1.272	0.338	1.262	0.99	1944	11	1875	21	2018	3	96
9c	rim	682	118	1767	0.0636	0.114	0.160	5.352	0.866	0.341	0.851	0.98	1877	7	1890	14	1863	3	101
10a	rim	743	616	2633	0.0852	0.111	0.181	3.808	1.133	0.249	1.119	0.99	1595	9	1431	14	1818	3	88
10c	rim	326	200	819	0.258	0.114	0.213	5.275	0.894	0.335	0.868	0.97	1865	8	1864	14	1866	4	100
11a	core	316	430	790	0.4326	0.114	0.290	5.063	0.969	0.323	0.924	0.95	1830	8	1805	15	1858	5	98
11b	rim	612	211	2006	0.0839	0.113	0.187	4.170	1.705	0.268	1.695	0.99	1668	14	1533	23	1843	3	91
11c	rim	3982	117833	4466	6.6346	0.108	1.600	4.391	2.638	0.294	2.098	0.80	1711	22	1663	31	1769	29	97
12a	core	97	58	116	0.5057	0.235	0.310	19.683	0.965	0.607	0.914	0.95	3076	9	3058	22	3088	5	100

Appendix 1, Table 4. U–Pb zircon data obtained in sample **SPN210189A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	core	117	83	402	0.206	0.119	0.981	4.050	2.399	0.246	2.189	0.91	1644	20	1419	28	1945	18	85
2a	rim	1644	92	12301	0.007	0.090	4.040	1.490	4.389	0.120	1.715	0.39	926	27	733	12	1420	77	65
2b	core	265	46	1127	0.041	0.110	0.669	3.154	1.843	0.209	1.717	0.93	1446	14	1223	19	1792	12	81
3a	core	44	29	99	0.292	0.121	0.778	6.124	1.245	0.368	0.973	0.78	1994	11	2019	17	1967	14	101
3a	core	71	44	169	0.26	0.123	1.033	5.941	1.822	0.352	1.501	0.82	1967	16	1943	25	1993	18	99
4a	core	285	4	770	0.005	0.114	0.389	5.219	0.911	0.332	0.824	0.90	1856	8	1849	13	1863	7	100
4b	rim	1267	45	11249	0.004	0.083	1.147	1.173	1.627	0.103	1.153	0.71	788	9	630	7	1267	22	62
5a	core	74	51	370	0.138	0.117	0.674	2.709	1.877	0.168	1.752	0.93	1331	14	999	16	1915	12	70
6a	core	61	35	143	0.246	0.121	0.481	6.001	0.991	0.360	0.866	0.87	1976	9	1981	15	1971	9	100
7a	core	240	14	648	0.021	0.122	3.427	5.535	3.593	0.329	1.082	0.30	1906	31	1832	17	1988	61	96
7b	rim	1249	263	24405	0.011	0.068	3.422	0.443	3.893	0.047	1.857	0.48	372	12	298	5	863	71	43
8a	overgrowth	1600	738	44626	0.017	0.060	2.752	0.277	3.294	0.033	1.810	0.55	248	7	212	4	606	60	41
8b	core	286	135	727	0.186	0.116	0.714	5.363	1.210	0.335	0.977	0.81	1879	10	1863	16	1897	13	99
9a	core	123	122	365	0.334	0.114	0.571	4.324	0.971	0.275	0.785	0.81	1698	8	1566	11	1864	10	91
10a	core	318	701	544	1.29	0.131	0.302	6.975	0.984	0.387	0.936	0.95	2108	9	2110	17	2107	5	100
11a	core	89	134	196	0.682	0.116	0.498	5.562	1.023	0.347	0.894	0.87	1910	9	1919	15	1901	9	101
12a	core	167	153	410	0.372	0.115	1.014	5.245	1.401	0.331	0.967	0.69	1860	12	1842	16	1880	18	99
12b	overgrowth	793	154	13740	0.011	0.061	3.007	0.456	3.124	0.054	0.846	0.27	382	10	339	3	648	65	59
13a	core	157	208	330	0.63	0.121	0.535	6.094	1.034	0.366	0.885	0.86	1989	9	2009	15	1969	10	101
13b	overgrowth	1490	555	8610	0.065	0.108	1.221	2.191	1.938	0.147	1.505	0.78	1178	14	885	12	1765	22	67
14a	core	566	213	1232	0.172	0.114	2.715	6.248	3.088	0.396	1.472	0.48	2011	27	2152	27	1869	49	108

Appendix 1, Table 5. U–Pb zircon data obtained in sample **MSI230042A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	core	44	72	94	0.76	0.125	2.681	5.944	2.916	0.346	1.146	0.39	1968	26	1914	19	2024	48	97
1b	overgrowth	–	54	6263	–	0.071	2.695	0.888	3.228	0.090	1.778	0.55	646	16	557	10	967	55	67
2	rim	–	9	676	–	0.111	4.634	4.747	4.869	0.309	1.492	0.31	1776	42	1736	23	1823	84	97
3a	core	79	166	149	1.06	0.128	0.812	6.493	1.567	0.368	1.341	0.86	2045	14	2021	23	2069	14	99
3b	rim	233	24	564	0.03	0.113	26.111	5.765	27.017	0.369	6.936	0.26	1941	266	2025	122	1853	488	105
4	core	287	653	582	1.08	0.126	0.993	5.971	1.793	0.343	1.493	0.83	1972	16	1901	25	2046	18	96
5	rim	241	358	601	0.65	0.120	3.334	5.088	3.720	0.308	1.651	0.44	1834	32	1729	25	1955	60	94
6a	core	154	307	333	0.92	0.121	0.432	5.536	1.125	0.333	1.038	0.92	1906	10	1852	17	1966	8	97
6b	rim	220	234	457	0.25	0.117	2.766	6.515	3.866	0.404	2.700	0.70	2048	35	2189	50	1908	50	107
7a	core	16	26	33	0.79	0.124	1.070	6.226	2.104	0.364	1.812	0.86	2008	19	1999	31	2017	19	100
7b	rim	204	11	612	0.00	0.113	0.539	4.638	1.168	0.299	1.035	0.89	1756	10	1686	15	1841	10	95
8	core	669	555	2211	0.23	0.108	0.229	3.841	1.531	0.258	1.513	0.99	1601	12	1477	20	1769	4	91
9a	core	71	143	144	0.99	0.124	0.706	6.001	1.391	0.352	1.199	0.86	1976	12	1945	20	2008	13	98
9b	rim	210	16	594	0.02	0.113	0.356	4.911	1.105	0.316	1.046	0.95	1804	9	1770	16	1844	6	98
10a	core	309	20	899	0.02	0.115	3.057	4.869	3.397	0.306	1.481	0.44	1797	29	1723	22	1884	55	95
10b	rim	185	6	524	0.01	0.113	0.331	4.951	1.223	0.316	1.177	0.96	1811	10	1772	18	1856	6	98
11	core	184	202	324	0.67	0.158	0.647	9.199	1.117	0.422	0.911	0.82	2358	10	2271	17	2434	11	97
12	core	20	21	49	0.39	0.122	1.594	5.627	2.155	0.335	1.451	0.67	1920	19	1861	24	1985	28	97
13	core	301	165	1031	0.25	0.167	1.023	5.440	5.423	0.237	5.326	0.98	1891	48	1369	66	2525	17	75
14	core	397	401	919	0.43	0.120	0.221	5.740	1.319	0.347	1.300	0.99	1937	11	1920	22	1956	4	99
15	rim	328	5	913	0.00	0.113	0.231	5.015	1.484	0.322	1.466	0.99	1822	13	1800	23	1847	4	99
16	core	137	240	283	0.85	0.123	0.374	6.015	1.330	0.354	1.276	0.96	1978	12	1952	22	2005	7	99

Appendix 1, Table 6. U–Pb zircon data obtained in sample **ELH230145B** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1	core	243	252	526	0.48	0.125	0.27	6.302	1.264	0.365	1.234	0.98	2019	11	2008	21	2030	5	99
2	core	212	132	477	0.27	0.126	0.281	6.436	1.325	0.370	1.295	0.98	2037	12	2028	23	2046	5	100
3	core	94	110	204	0.55	0.123	0.470	6.146	1.580	0.361	1.508	0.95	1997	14	1987	26	2007	8	99
4a	rim	125	25	311	0.06	0.128	1.491	6.226	2.238	0.352	1.670	0.75	2008	20	1944	28	2074	26	97
4b	core	389	231	617	0.38	0.184	1.109	12.428	1.694	0.490	1.280	0.76	2637	16	2570	27	2690	18	98
5	core	20	33	61	0.52	0.094	1.086	3.428	1.797	0.264	1.432	0.80	1511	14	1510	19	1512	20	100
6a	core	38	66	100	0.65	0.102	0.767	4.131	1.610	0.294	1.415	0.88	1661	13	1662	21	1659	14	100
6b	overgrowth	227	128	653	0.19	0.103	0.308	4.256	1.368	0.300	1.333	0.97	1685	11	1692	20	1676	6	101
7a	core	249	318	552	0.57	0.120	0.276	5.823	1.211	0.351	1.179	0.97	1950	11	1940	20	1961	5	99
7b	overgrowth	1551	1096	9344	0.11	0.091	0.233	1.854	1.534	0.148	1.516	0.99	1065	10	888	13	1446	4	74
8	core	36	29	50	0.59	0.189	0.615	13.625	1.503	0.522	1.371	0.91	2724	14	2709	30	2735	10	100
9a	core	195	280	446	0.61	0.116	0.402	5.405	1.443	0.338	1.386	0.96	1886	12	1878	23	1894	7	100
9b	core	214	289	516	0.57	0.116	0.296	5.182	1.260	0.325	1.225	0.97	1850	11	1814	19	1890	5	98
10	core	117	254	215	1.18	0.127	0.413	6.529	1.301	0.371	1.234	0.95	2050	12	2036	22	2063	7	99
11	core	357	617	460	1.33	0.183	0.272	12.661	1.198	0.501	1.167	0.97	2655	11	2618	25	2683	4	99
12	core	128	82	292	0.26	0.124	0.354	6.247	1.172	0.366	1.118	0.95	2011	10	2010	19	2012	6	100
13	core	103	81	149	0.54	0.185	0.362	13.118	1.410	0.515	1.363	0.97	2688	13	2679	30	2695	6	100
14	core	165	158	385	0.42	0.118	0.334	5.628	1.485	0.346	1.447	0.97	1920	13	1915	24	1927	6	100
15	core	42	40	67	0.56	0.190	0.566	12.319	1.397	0.471	1.277	0.91	2629	13	2487	26	2740	9	96
16	core	94	23	232	0.10	0.122	0.444	5.952	1.335	0.353	1.259	0.94	1969	12	1948	21	1990	8	99

Appendix 1, Table 7. U–Pb zircon data obtained in sample **SPN230513A** using in–situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	core	91	172	176	0.99	0.123	0.469	6.207	1.254	0.367	1.163	0.93	2005	11	2016	20	1994	8	101
1b	rim	103	23	271	0.08	0.114	0.409	5.259	1.181	0.335	1.108	0.94	1862	10	1862	18	1863	7	100
2a	core	319	127	824	0.15	0.115	0.227	5.279	1.607	0.334	1.591	0.99	1865	14	1856	26	1876	4	99
2b	rim	348	107	918	0.11	0.115	0.477	5.229	1.407	0.331	1.324	0.94	1857	12	1843	21	1874	9	99
3a	core	103	31	270	0.12	0.114	0.452	5.231	2.978	0.332	2.943	0.99	1858	26	1849	47	1867	8	99
3b	core	182	71	508	0.14	0.114	1.535	4.873	2.089	0.310	1.416	0.68	1798	18	1740	22	1866	28	96
4a	core	229	533	422	1.26	0.124	0.346	6.227	1.317	0.366	1.271	0.96	2008	12	2009	22	2008	6	100
4b	core	67	58	157	0.34	0.120	0.526	5.756	1.253	0.348	1.137	0.91	1940	11	1926	19	1954	9	99
5a	core	295	81	505	0.17	0.179	0.229	11.733	1.418	0.476	1.399	0.99	2583	13	2508	29	2643	4	98
5b	rim	209	86	664	0.14	0.114	0.464	4.264	1.401	0.272	1.322	0.94	1686	12	1552	18	1858	8	91
6	core	137	93	373	0.24	0.114	0.408	4.861	1.147	0.309	1.072	0.93	1796	10	1738	16	1863	7	96
7a	core	156	109	378	0.27	0.117	0.329	5.583	1.429	0.346	1.391	0.97	1913	12	1915	23	1912	6	100
7b	rim	289	78	853	0.07	0.115	2.409	4.723	2.789	0.299	1.405	0.50	1771	24	1685	21	1874	43	95
8a	core	48	27	66	0.40	0.204	0.548	15.521	1.647	0.551	1.553	0.94	2848	16	2831	36	2860	9	100
8b	rim	251	120	917	0.12	0.110	1.126	3.634	1.915	0.239	1.549	0.81	1557	15	1383	19	1802	20	86
9	core	188	62	535	0.14	0.115	2.436	4.846	3.081	0.304	1.887	0.61	1793	26	1713	28	1887	44	95
10a	core	61	97	139	0.76	0.124	0.714	5.582	1.301	0.327	1.088	0.84	1913	11	1822	17	2014	13	95
10b	rim	–	30	1205	–	0.113	9.028	4.270	9.611	0.275	3.297	0.34	1688	82	1565	46	1843	164	92
11a	core	25	15	54	0.31	0.122	4.632	6.460	7.099	0.383	5.379	0.76	2040	64	2088	97	1993	82	102
11b	rim	523	141	1801	0.08	0.115	2.201	4.051	2.857	0.255	1.822	0.64	1645	24	1464	24	1884	40	87
12	core	202	75	530	0.14	0.115	0.305	5.210	1.328	0.330	1.292	0.97	1854	11	1836	21	1875	6	99
13	core	215	243	321	0.78	0.188	0.285	12.369	1.511	0.478	1.484	0.98	2633	14	2519	31	2721	5	97

Appendix 2. U–Pb zircon data obtained in granodioritic and migmatitic samples

Appendix 2, Table 1. U–Pb zircon data obtained in sample **ELH23187A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb		²⁰⁷ Pb/ ²³⁵ U		²⁰⁶ Pb/ ²³⁸ U		Rho	²⁰⁷ Pb/ ²³⁵ U		Age (Ma)		²⁰⁷ Pb/ ²⁰⁶ Pb		% Conc
						1σ		1σ		1σ			±σ		±σ		±σ		
1a	core	187	59	482	0.12	0.115	0.295	5.354	1.490	0.337	1.460	0.98	1878	13	1875	24	1881	5	100
1b	overgrowth	2436	154	11821	0.01	0.094	2.909	2.424	6.767	0.188	6.109	0.90	1250	50	1110	63	1500	55	83
2	core	756	405	1908	0.21	0.114	0.165	5.324	1.484	0.337	1.474	0.99	1873	13	1874	24	1871	3	100
3	core	201	48	531	0.09	0.114	0.294	5.218	1.826	0.333	1.803	0.99	1856	16	1851	29	1861	5	100
4a	core	209	38	548	0.07	0.115	0.274	5.343	1.524	0.337	1.500	0.98	1876	13	1872	24	1880	5	100
5a	core	164	37	426	0.08	0.115	0.325	5.341	1.516	0.337	1.481	0.98	1875	13	1874	24	1877	6	100
5b	rim	296	94	781	0.11	0.115	0.256	5.238	1.316	0.331	1.291	0.98	1859	11	1844	21	1875	5	99
4b	overgrowth	272	188	881	0.13	0.115	0.843	4.240	1.751	0.268	1.535	0.88	1682	14	1528	21	1879	15	89
6	core	167	46	435	0.10	0.115	0.303	5.315	1.629	0.336	1.601	0.98	1871	14	1867	26	1876	5	100
7a	core	143	78	440	0.12	0.116	0.564	4.506	1.962	0.283	1.879	0.96	1732	16	1605	27	1889	10	92
7b	rim	365	159	1015	0.14	0.114	0.234	4.902	1.138	0.311	1.113	0.98	1803	10	1746	17	1869	4	96
8a	core	425	212	1090	0.19	0.114	0.205	5.246	1.388	0.333	1.372	0.99	1860	12	1852	22	1869	4	100
8b	overgrowth	640	213	1944	0.10	0.115	0.841	4.545	1.879	0.288	1.681	0.89	1739	16	1630	24	1874	15	93
9	core	43	34	109	0.31	0.113	0.667	5.159	1.698	0.330	1.562	0.92	1846	15	1839	25	1854	12	100
10a	core	169	49	434	0.12	0.115	0.380	5.368	1.657	0.339	1.613	0.97	1880	14	1882	26	1878	7	100
10b	overgrowth	965	71	3084	0.02	0.112	0.281	4.333	1.576	0.280	1.551	0.98	1700	13	1590	22	1838	5	92
11a	core	70	73	155	0.47	0.122	0.475	6.052	1.798	0.360	1.734	0.96	1983	16	1982	30	1985	8	100
11b	rim	635	105	1757	0.06	0.114	0.286	5.029	1.624	0.320	1.599	0.98	1824	14	1787	25	1866	5	98
12a	core	90	34	251	0.10	0.114	0.584	4.940	1.413	0.314	1.286	0.91	1809	12	1758	20	1868	11	97
12b	rim	231	80	616	0.13	0.114	0.275	5.127	1.386	0.327	1.358	0.98	1841	12	1823	22	1861	5	99
13a	core	45	55	62	0.86	0.184	0.542	12.930	1.592	0.509	1.496	0.94	2675	15	2651	33	2692	9	99
13b	rim	354	32	1164	0.03	0.111	0.303	4.166	1.340	0.271	1.305	0.97	1667	11	1546	18	1823	6	91
14	rim	66	61	213	0.16	0.115	0.571	4.228	2.771	0.268	2.712	0.98	1679	23	1530	37	1872	10	90

Appendix 2, Table 2. U-Pb zircon data obtained in sample **MSI230176A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	core	246	82	638	0.13	0.115	0.265	5.296	1.363	0.334	1.337	0.98	1868	12	1859	22	1878	5	99
1b	rim	277	94	724	0.13	0.115	0.286	5.250	1.475	0.332	1.447	0.98	1861	13	1847	23	1876	5	99
2	core	509	383	1346	0.27	0.115	0.317	5.026	2.659	0.317	2.640	0.99	1824	23	1775	41	1879	6	97
3	rim	209	61	539	0.11	0.114	0.295	5.313	1.555	0.337	1.527	0.98	1871	13	1872	25	1869	5	100
4a	core	148	35	385	0.09	0.115	0.351	5.362	1.800	0.338	1.765	0.98	1879	16	1875	29	1883	6	100
4b	rim	383	39	1021	0.03	0.114	0.208	5.248	1.342	0.334	1.326	0.99	1860	12	1856	21	1865	4	100
5a	core	410	233	1154	0.20	0.115	0.688	4.801	1.650	0.303	1.500	0.91	1785	14	1704	23	1881	12	95
5b	rim	228	71	612	0.11	0.115	0.307	5.171	1.398	0.325	1.364	0.98	1848	12	1813	22	1887	6	98
6	core	219	82	578	0.15	0.114	0.282	5.161	1.438	0.327	1.410	0.98	1846	12	1825	22	1871	5	99
7	core	335	206	846	0.24	0.115	0.293	5.312	1.420	0.335	1.389	0.98	1871	12	1862	23	1881	5	99
8a	core	200	61	534	0.13	0.114	0.340	5.137	1.541	0.326	1.502	0.98	1842	13	1819	24	1868	6	99
8b	rim	328	69	874	0.08	0.114	0.301	5.205	1.327	0.330	1.293	0.97	1853	11	1839	21	1869	5	99
9a	core	375	235	1189	0.18	0.113	0.454	4.242	2.554	0.271	2.513	0.98	1682	21	1546	35	1856	8	91
9b	rim	198	68	555	0.12	0.115	1.056	4.918	1.386	0.310	0.898	0.65	1805	12	1743	14	1878	19	96
10a	core	233	109	606	0.18	0.115	0.310	5.214	1.362	0.330	1.326	0.97	1855	12	1836	21	1876	6	99
10b	rim	262	92	694	0.13	0.115	0.254	5.201	1.306	0.328	1.281	0.98	1853	11	1828	20	1880	5	99
11	core	279	136	723	0.19	0.114	0.253	5.196	1.205	0.331	1.178	0.98	1852	10	1842	19	1864	5	99
12	core	237	79	655	0.12	0.115	0.298	4.983	1.694	0.314	1.667	0.98	1817	14	1761	26	1881	5	97
13a	core	166	64	463	0.14	0.115	0.344	4.916	1.387	0.310	1.343	0.97	1805	12	1741	21	1880	6	96
13b	rim	156	54	409	0.13	0.114	0.331	5.236	1.306	0.332	1.263	0.97	1858	11	1847	20	1871	6	99

Appendix 2, Table 3. U–Pb zircon data obtained in sample **SPN230377A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1	core	87	82	194	0.41	0.121	0.434	6.067	1.391	0.362	1.321	0.95	1986	12	1994	23	1977	8	100
2a	core	147	210	332	0.50	0.122	0.419	5.882	1.305	0.349	1.236	0.95	1959	11	1931	21	1988	7	99
2b	overgrowth	316	3	851	0.00	0.114	0.222	5.260	1.390	0.333	1.372	0.99	1862	12	1855	22	1871	4	100
3	core	43	57	84	0.69	0.129	0.818	6.837	1.641	0.384	1.423	0.87	2090	15	2097	26	2084	14	100
4	core	147	144	323	0.44	0.125	0.330	6.249	1.511	0.362	1.474	0.98	2011	13	1994	25	2030	6	99
5	core	486	57	891	0.06	0.164	2.131	10.412	3.172	0.462	2.350	0.74	2472	30	2448	48	2492	36	99
6	core	113	226	224	1.01	0.122	0.407	6.037	1.513	0.358	1.457	0.96	1981	13	1972	25	1991	7	100
7	overgrowth	355	4	953	0.00	0.114	0.214	5.259	1.453	0.334	1.437	0.99	1862	12	1859	23	1866	4	100
8	core	118	74	282	0.20	0.123	0.385	6.020	1.502	0.354	1.452	0.97	1979	13	1955	25	2004	7	99
9	core	43	86	84	1.01	0.121	0.668	6.061	1.621	0.363	1.477	0.91	1985	14	1995	25	1974	12	101
10a	core	377	464	436	0.90	0.224	0.185	18.189	1.550	0.589	1.539	0.99	3000	15	2987	37	3008	3	100
10b	overgrowth	369	4	996	0.00	0.114	0.209	5.219	1.442	0.332	1.427	0.99	1856	12	1850	23	1862	4	100
11a	core	321	264	482	0.56	0.183	0.357	12.580	1.590	0.500	1.549	0.97	2649	15	2612	33	2677	6	99
11b	overgrowth	384	3	1035	0.00	0.114	0.207	5.230	1.410	0.333	1.395	0.99	1857	12	1853	22	1863	4	100
12	core	93	24	224	0.11	0.121	0.410	6.030	1.447	0.361	1.388	0.96	1980	13	1989	24	1971	7	100
13	core	114	148	246	0.60	0.122	0.514	6.028	1.360	0.359	1.259	0.93	1980	12	1977	21	1983	9	100
14a	core	212	324	446	0.72	0.121	0.295	5.966	1.410	0.358	1.378	0.98	1971	12	1972	23	1970	5	100
14b	overgrowth	399	6	1076	0.00	0.114	0.203	5.214	1.379	0.333	1.364	0.99	1855	12	1852	22	1858	4	100
15a	core	134	113	316	0.22	0.122	0.337	6.028	1.410	0.357	1.369	0.97	1980	12	1970	23	1990	6	99
15b	overgrowth	334	4	899	0.00	0.114	0.220	5.241	1.446	0.334	1.429	0.99	1859	12	1857	23	1862	4	100

Appendix 2, Table 4. U–Pb zircon data obtained in sample **MSI230137A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1	core	475	642	612	1.04	0.189	0.436	13.722	1.805	0.526	1.752	0.97	2731	17	2723	39	2736	7	100
2	core	83	206	188	0.57	0.124	0.711	5.839	1.223	0.342	0.995	0.81	1952	11	1898	16	2010	13	97
3	core	109	185	134	1.35	0.192	1.354	13.816	1.907	0.522	1.343	0.70	2737	18	2706	30	2760	22	99
4	core	156	279	294	0.94	0.129	0.367	6.751	1.250	0.379	1.195	0.96	2079	11	2069	21	2089	6	100
5a	core	55	133	105	1.26	0.121	0.628	5.922	1.357	0.355	1.203	0.89	1964	12	1956	20	1973	11	100
5b	overgrowth	406	8	1087	0.01	0.115	0.299	5.289	1.438	0.335	1.406	0.98	1867	12	1860	23	1875	5	100
6	core	106	258	218	0.88	0.122	0.428	5.988	1.402	0.356	1.335	0.95	1974	12	1962	23	1987	8	99
7a	rim	441	26	1156	0.02	0.117	0.192	5.467	1.233	0.340	1.218	0.99	1895	11	1884	20	1907	3	99
7b	core	81	85	184	0.46	0.122	0.463	5.952	1.431	0.354	1.354	0.95	1969	13	1952	23	1986	8	99
8a	core	164	187	272	0.33	0.196	0.386	12.612	1.175	0.467	1.109	0.94	2651	11	2471	23	2791	6	95
8b	overgrowth	647	8	1747	0.00	0.114	0.158	5.227	1.377	0.332	1.368	0.99	1857	12	1848	22	1867	3	99
9	core	76	41	178	0.23	0.121	0.474	5.964	1.454	0.358	1.375	0.95	1971	13	1974	23	1967	8	100
10	core	154	215	337	0.63	0.119	0.346	5.805	1.374	0.353	1.330	0.97	1947	12	1948	22	1946	6	100
11	core	164	158	243	0.60	0.187	0.311	12.890	1.355	0.499	1.319	0.97	2672	13	2610	28	2718	5	98
12	core	42	30	99	0.31	0.120	0.638	5.859	1.376	0.353	1.219	0.89	1955	12	1951	21	1960	11	100
13	core	352	950	365	2.60	0.186	0.326	12.999	1.299	0.508	1.257	0.97	2680	12	2649	27	2703	5	99
14	core	53	68	114	0.60	0.120	0.636	5.986	1.400	0.361	1.247	0.89	1974	12	1985	21	1962	11	101
15	core	71	194	219	0.34	0.116	0.519	4.255	1.640	0.266	1.556	0.95	1685	14	1521	21	1895	9	89
16	core	82	112	184	0.55	0.121	0.461	5.798	1.433	0.347	1.357	0.95	1946	12	1921	23	1973	8	99
17	core	430	500	916	0.56	0.124	0.392	6.233	1.186	0.365	1.120	0.94	2009	10	2008	19	2010	7	100
18	core	92	671	261	0.25	0.118	0.448	4.824	1.090	0.297	0.994	0.91	1789	9	1674	15	1926	8	93
19a	core	58	122	115	1.07	0.122	0.581	5.891	1.426	0.351	1.302	0.91	1960	12	1937	22	1984	10	99
19b	overgrowth	404	103	1172	0.06	0.117	0.215	4.912	1.169	0.304	1.149	0.98	1804	10	1711	17	1914	4	94
20a	core	75	130	154	0.85	0.123	0.503	6.068	1.676	0.358	1.598	0.95	1986	15	1974	27	1998	9	99
20b	overgrowth	458	4	1345	0.00	0.114	0.282	4.788	1.183	0.305	1.149	0.97	1783	10	1718	17	1859	5	96
21	core	33	41	45	0.91	0.183	0.649	12.927	1.556	0.511	1.414	0.91	2674	15	2663	31	2683	11	100
22	core	158	90	404	0.21	0.121	0.355	5.520	1.955	0.331	1.923	0.98	1904	17	1844	31	1970	6	97
23	core	350	135	881	0.15	0.118	0.222	5.543	1.338	0.342	1.320	0.99	1907	12	1894	22	1921	4	99

Appendix 3. U–Pb zircon data obtained in metavolcanic rock samples

Appendix 3, Table 1. U–Pb zircon data obtained in sample **SPN221204A** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	core	162	178	386	0.45	0.115	0.302	5.358	0.874	0.337	0.820	0.94	1878	8	1873	13	1884	5	100
2a	core	298	384	717	0.52	0.114	0.229	5.188	0.937	0.329	0.908	0.97	1851	8	1832	15	1872	4	99
3a	core	88	231	846	0.28	0.058	0.526	0.728	0.909	0.090	0.741	0.82	556	4	558	4	545	11	102
4a	rim	180	98	466	0.20	0.114	0.275	5.209	0.968	0.330	0.928	0.96	1854	8	1839	15	1871	5	99
5a	core	216	143	539	0.26	0.115	0.251	5.332	0.818	0.336	0.778	0.95	1874	7	1869	13	1880	5	100
6a	core	180	259	616	0.24	0.114	0.335	3.903	1.299	0.248	1.255	0.97	1614	11	1426	16	1870	6	86
7a	core	216	115	542	0.21	0.115	0.250	5.370	0.973	0.339	0.940	0.97	1880	8	1884	15	1876	5	100
8a	core	146	111	450	0.26	0.113	0.760	4.238	1.365	0.273	1.134	0.83	1681	11	1556	16	1842	14	91
9a	core	763	340	4151	0.11	0.098	0.802	2.198	2.049	0.163	1.885	0.92	1180	14	972	17	1585	15	74
10a	core	404	480	998	0.47	0.115	0.215	5.122	1.302	0.323	1.284	0.99	1840	11	1807	20	1878	4	98
11a	core	412	167	1060	0.15	0.115	0.181	5.323	0.907	0.336	0.888	0.98	1873	8	1865	14	1881	3	100
12a	core	171	149	410	0.35	0.115	0.467	5.435	1.530	0.343	1.457	0.95	1890	13	1899	24	1881	8	100
13a	core	633	353	1617	0.21	0.115	0.146	5.272	0.841	0.333	0.829	0.98	1864	7	1852	13	1878	3	99
14	core	168	64	430	0.15	0.115	0.283	5.356	0.839	0.337	0.790	0.94	1878	7	1872	13	1884	5	100
15a	core	166	43	437	0.10	0.115	0.350	5.255	0.931	0.332	0.863	0.93	1862	8	1847	14	1878	6	99
16a	core	183	59	471	0.12	0.115	0.274	5.359	0.796	0.338	0.748	0.94	1878	7	1877	12	1880	5	100
17a	core	125	190	286	0.67	0.115	0.365	5.300	0.948	0.335	0.875	0.92	1869	8	1863	14	1875	7	100
18a	core	291	166	404	0.38	0.199	0.180	15.153	0.745	0.553	0.723	0.97	2825	7	2838	17	2815	3	100
20a	core	230	108	597	0.18	0.115	0.242	5.232	0.856	0.331	0.821	0.96	1858	7	1843	13	1875	4	99

Appendix 3, Table 2. U–Pb zircon data obtained in sample **MSI230033C** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1	core	77	131	93	1.39	0.185	0.452	13.391	1.706	0.525	1.645	0.96	2708	16	2722	37	2697	7	100
2	core	136	162	259	0.62	0.137	0.348	7.562	1.342	0.400	1.296	0.97	2180	12	2171	24	2189	6	100
3	rim	55	77	116	0.65	0.123	0.573	6.090	1.432	0.360	1.312	0.92	1989	13	1982	22	1996	10	100
4	rim	59	65	131	0.50	0.122	0.545	6.020	1.538	0.357	1.438	0.93	1979	13	1969	24	1988	10	100
5	rim	132	223	280	0.78	0.121	0.389	5.858	1.338	0.350	1.280	0.96	1955	12	1937	21	1974	7	99
6	rim	31	51	63	0.80	0.123	0.768	6.219	1.541	0.366	1.336	0.87	2007	14	2011	23	2003	14	100
7a	core	91	84	128	0.69	0.188	0.722	13.411	2.989	0.517	2.901	0.97	2709	29	2686	64	2726	12	99
7b	rim	109	93	218	0.54	0.187	1.436	9.698	4.946	0.376	4.733	0.96	2407	47	2059	84	2715	24	89
8	core	111	133	257	0.52	0.123	1.210	5.762	1.766	0.340	1.286	0.73	1941	15	1886	21	2000	21	97
9	core	54	33	118	0.28	0.128	0.547	6.656	1.429	0.377	1.320	0.92	2067	13	2063	23	2070	10	100
10a	core	134	64	317	0.17	0.121	0.595	6.024	1.393	0.361	1.260	0.90	1979	12	1985	22	1973	11	100
10b	rim	185	30	455	0.06	0.122	0.371	5.970	1.285	0.356	1.231	0.96	1971	11	1964	21	1979	7	100
11a	rim	201	215	459	0.47	0.120	0.301	5.759	1.266	0.349	1.229	0.97	1940	11	1931	21	1950	5	99
11b	overgrowth	14	6	38	0.15	0.117	1.237	5.277	2.045	0.326	1.628	0.80	1865	18	1818	26	1918	22	97
12	core	155	141	348	0.41	0.122	0.340	6.009	1.461	0.358	1.421	0.97	1977	13	1973	24	1982	6	100
13a	core	79	49	115	0.42	0.198	0.501	14.313	1.500	0.525	1.414	0.94	2771	14	2722	31	2807	8	99
13b	overgrowth	157	73	275	0.27	0.170	1.199	10.779	1.591	0.460	1.046	0.66	2504	15	2439	21	2558	20	98
14a	core	140	130	198	0.66	0.197	0.413	13.975	2.225	0.514	2.187	0.98	2748	21	2673	48	2804	7	98
14b	overgrowth	13	1	35	0.00	0.121	1.412	5.612	2.213	0.336	1.705	0.77	1918	19	1867	28	1973	25	97
15	core	152	112	356	0.31	0.122	0.335	5.946	1.249	0.353	1.203	0.96	1968	11	1950	20	1987	6	99
16	core	82	129	173	0.75	0.122	0.469	5.988	1.775	0.356	1.712	0.96	1974	16	1962	29	1987	8	99
17a	core	547	594	1316	0.41	0.120	0.507	5.560	3.017	0.336	2.974	0.99	1910	26	1866	48	1958	9	98
17b	overgrowth	212	3	527	0.01	0.122	0.276	5.987	1.326	0.357	1.297	0.98	1974	12	1969	22	1980	5	100
18a	core	149	401	300	1.33	0.122	0.721	5.586	1.528	0.331	1.347	0.88	1914	13	1844	22	1991	13	96
18b	rim	435	120	1147	0.10	0.117	0.193	5.335	1.349	0.331	1.335	0.99	1875	12	1843	21	1909	3	98
19	core	180	394	378	1.00	0.122	1.523	5.707	2.037	0.338	1.353	0.66	1932	18	1878	22	1991	27	97
20	core	100	49	243	0.20	0.121	0.812	5.802	1.542	0.348	1.310	0.85	1947	13	1925	22	1970	14	99
21	core	188	67	462	0.14	0.122	0.330	5.861	1.209	0.350	1.163	0.96	1955	11	1934	19	1979	6	99

Appendix 3, Table 3. U–Pb zircon data obtained in sample **ELH210128A** using in–situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	rim	455	300	1300	0.22	0.113	0.317	4.644	0.724	0.298	0.651	0.90	1757	6	1682	10	1847	6	95
1b	core	404	439	1319	0.29	0.108	0.566	3.831	0.897	0.257	0.696	0.78	1599	7	1474	9	1768	10	90
2a	rim	139	406	1370	0.21	0.091	16.480	1.107	16.594	0.088	1.942	0.12	757	93	545	10	1447	318	52
3a	rim	352	106	1065	0.02	0.110	0.719	4.485	1.027	0.296	0.733	0.71	1728	9	1674	11	1795	13	96
3b	core	157	203	360	0.54	0.123	0.935	5.769	1.195	0.341	0.744	0.62	1942	10	1891	12	1997	17	97
4a	core	256	221	992	0.21	0.103	0.891	3.138	1.580	0.221	1.305	0.83	1442	12	1290	15	1674	16	86
5a	core	278	269	936	0.26	0.114	7.397	3.925	7.507	0.250	1.282	0.17	1619	63	1438	17	1863	134	87
6a	core	448	343	1108	0.31	0.114	0.296	5.293	0.741	0.336	0.679	0.92	1868	6	1867	11	1868	5	100
7a	rim	326	240	938	0.24	0.111	0.393	4.519	0.764	0.295	0.655	0.86	1734	6	1666	10	1818	7	95
8a	core	510	2589	6259	0.38	0.059	1.352	0.567	1.654	0.069	0.953	0.58	456	6	432	4	582	29	78
9a	core	178	102	461	0.21	0.114	0.534	5.171	0.894	0.329	0.718	0.80	1848	8	1833	11	1865	10	99
10a	rim	286	169	742	0.23	0.115	0.375	5.163	0.795	0.327	0.701	0.88	1847	7	1823	11	1873	7	99
11a	core	200	456	386	1.18	0.122	0.757	5.970	1.044	0.354	0.719	0.69	1971	9	1954	12	1990	13	99
11b	rim	408	306	3848	0.05	0.076	2.279	1.011	2.405	0.097	0.766	0.32	709	12	597	4	1083	46	66
12a	rim	377	598	1836	0.27	0.100	0.549	2.407	1.519	0.174	1.416	0.93	1245	11	1033	14	1632	10	76
12b	core	328	219	917	0.22	0.113	0.418	4.757	0.823	0.305	0.709	0.86	1777	7	1715	11	1852	8	96
13a	rim	460	313	1219	0.25	0.114	0.316	5.012	0.733	0.318	0.661	0.90	1821	6	1780	10	1869	6	97
13b	core	293	224	747	0.30	0.115	0.371	5.165	0.816	0.326	0.727	0.89	1847	7	1821	12	1876	7	98
14a	core	198	129	530	0.21	0.115	1.536	5.038	1.697	0.318	0.722	0.43	1826	14	1782	11	1876	28	97

Appendix 3, Table 4. U-Pb zircon data obtained in sample **ELH210117B** using in-situ isotopic analysis by SIMS.

Zircon number	Spot location	Pb (ppm)	Th (ppm)	U (ppm)	Th/U Calc ¹	²⁰⁷ Pb/ ²⁰⁶ Pb	1σ	²⁰⁷ Pb/ ²³⁵ U	1σ	²⁰⁶ Pb/ ²³⁸ U	1 σ	Rho	Age (Ma)						% Conc
													²⁰⁷ Pb/ ²³⁵ U	±σ	²⁰⁶ Pb/ ²³⁸ U	±σ	²⁰⁷ Pb/ ²⁰⁶ Pb	±σ	
1a	rim	1388	61	2244	0.10	0.115	1.021	8.549	1.352	0.541	0.886	0.66	2291	12	2788	20	1873	18	122
1b	core	203	142	543	0.29	0.123	1.017	5.252	1.453	0.310	1.038	0.71	1861	12	1740	16	1999	18	93
1c	core	155	144	463	0.35	0.120	1.044	4.536	1.289	0.275	0.756	0.59	1738	11	1564	11	1954	19	89
2a	rim	388	7	1009	0.01	0.113	1.118	5.372	1.436	0.345	0.902	0.63	1880	12	1912	15	1846	20	102
2b	core	52	107	111	1.03	0.121	1.155	5.522	1.441	0.332	0.861	0.60	1904	12	1849	14	1965	21	97
2c	rim	71	156	204	0.94	0.116	2.388	4.005	2.570	0.249	0.949	0.37	1635	21	1435	12	1903	43	86
3a	core	131	6	353	0.02	0.114	0.501	5.191	0.845	0.331	0.680	0.81	1851	7	1844	11	1859	9	100
3b	core	197	260	469	0.56	0.114	0.447	5.192	0.822	0.330	0.690	0.84	1851	7	1836	11	1868	8	99