

Proterozoic zircon dates from auriferous zones at the Island Gold deposit: implications for late
gold remobilization in the Superior Province

by

Sophie Marie Gagnon

A thesis

presented to the University of Waterloo

in fulfilment of the

thesis requirement for the degree of

Master of Science

in

Earth Sciences

Waterloo, Ontario, Canada, 2024

© Sophie Marie Gagnon 2024

Author's declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that this thesis may be made electronically available to the public.

Statement of Contributions

This thesis is my own work. The following sections are co-authored with the following contributors:

Section 4.3.1 Whole Rock Geochemistry – Activation Laboratories collected the whole rock geochemical data used in this thesis.

Section 4.3.2 Oxygen-Hydrogen Isotopes - Queen's Facility for Isotope Research, Queen's University collected the oxygen-hydrogen data used in this thesis.

Section 4.3.3 Sulfur Isotopes - Environmental Isotope Lab, University of Waterloo collected the sulfur isotope data.

Abstract

The Island Gold deposit is a high-grade Archean orogenic gold deposit within the Michipicoten greenstone belt of the Superior Province. Hosted within the ~2750 Ma felsic to intermediate Wawa metavolcanic assemblage, gold mineralization has been constrained to between ~2680 and 2673 Ma. However, anomalous Proterozoic ages have been discovered within auriferous alteration zones, suggesting that late hydrothermal activity may have affected the deposit and potentially remobilized gold. Mineralization is hosted within quartz ($\pm$ carbonate) veins, with minimal mineralization within the surrounding altered host rock. To investigate the occurrence and spatial distribution of these anomalous young ages within the deposit, samples along an alteration gradient (weakly to strongly altered) adjacent to auriferous quartz $\pm$ carbonate veins, and from differing depths within the ore zone were examined. U–Pb LA-ICP-MS analyses of zircon from strongly altered auriferous zones yielded Archean protolith dates as well as Mesoproterozoic and early Paleozoic to late Mesozoic dates. Compared to Archean zircons in the host metavolcanic rocks, the younger zircons have generally higher concentrations of heavy rare earth elements and moderate enrichment in Y, Ta, U, and Th. We interpret the Mesoproterozoic ages to represent fluid–rock interaction during the Mid-Continent Rift, whereas the Paleozoic to Mesozoic grouping may be related to alkalic/kimberlitic activity within the area associated with the Great Meteor Hotspot track. It is unclear if these fluids had compositions amenable for large-scale gold mobilization, but they may have played a role in locally distributing gold throughout the Island Gold deposit. An increasing number of reported Proterozoic dates from accessory minerals in Archean gold deposits suggests that post-Archean processes are a potential complication for understanding the distribution of gold and has regional implications for gold exploration in the Superior Province.

Acknowledgements

I would first like to thank my supervisor, Prof. Chris Yakymchuk, for his continuous patience, support, and guidance on this journey. I would also like to thank my co-supervisor, Prof. Shoufa Lin for providing invaluable feedback, as well as the rest of my advisory committee, Prof. Brian Kendall and Prof. Shaun Frape for their suggestions and advice. A massive thank you to Ivan Edgeworth for all his help with the laser ablation system – it's a tricky beast that I wouldn't have been able to handle without his aid.

This project was made possible through financial support from Newmont Gold (through the SEG Student Research Grant) and Island Gold. I thank them for their generous contributions that funded several analytical techniques used in this study.

I would like to also thank the Island Gold personnel, including Michele Cote for sharing her extensive geological knowledge, and the underground geological team for their time and expertise at Island Gold.

Finally, I would like to thank the people in my life who helped support me through this wonderful and challenging task. My parents, sister, and brother for listening to me go on and on about my project, despite not being interested in geology. My peers within the Earth Science department; Carson, Sebastien, Ludo, Ivan, and Jill for our conversations about science and everything else; and Zach Adam, my rock, without whom this thesis would not have been possible. Thank you all for your kindness, your encouragement, and the joy you brought to my every day.

Table of Contents

Author's declaration.....	ii
Statement of Contributions	iii
Abstract	iv
Acknowledgements.....	v
List of Figures	viii
List of Tables	xi
1.0 Introduction.....	1
2.0 Background.....	2
2.1 Orogenic Gold Deposits.....	2
2.2 Regional Geology	3
2.3 Island Gold Geology	8
3.0 Methods	12
3.1 Overview	12
3.2 Petrography	12
3.3 LA-ICP-MS.....	12
3.3.1 Geochronology Analytical Parameters	14
3.3.2 Trace Elements Analytical Parameters	15
3.3.3 Geochronology QA/QC	16
3.4 Whole Rock Geochemistry	19
3.5 Oxygen-Hydrogen Isotopes	20
3.6 Sulfur Isotopes	20
4.0 Results.....	21
4.1 Sample Summary	21
4.1.1 Sample Classification.....	26
4.2 Geochronology.....	35
4.2.1 Summary	35
4.2.2 Protolith-aged Samples	40
4.2.3 Archean ages: two subsets	54
4.2.4 Archean and Proterozoic to Phanerozoic dates.....	70
4.3 Whole Rock Geochemistry, Stable Isotopes, and Zircon Trace Elements	82
4.3.1 Whole Rock Geochemistry	82
4.3.2 Oxygen-Hydrogen Isotopes	87
4.3.3 Sulfur Isotopes	87
4.3.4 Zircon Trace Element Concentrations	88
5.0 Discussion.....	97
5.1 O-H and S Isotopes	97
5.2 Geochronology.....	99
5.2.1 Mechanisms of Zircon Recrystallization and Re-setting	103
5.2.2 Younger Archean Date Groups.....	105
5.3 Post-Archean dates.....	108
5.4 Implications for Gold Remobilization	113
6.0 Conclusions.....	115
7.0 Future Work.....	116
References.....	118
Appendix A: U-Pb Secondary standard concordia diagrams	128

Appendix B: LA-ICP-MS U-Pb Isotope Data, and U-Pb Age Data.....	131
Appendix C: Sulfur Isotopes.....	168
Appendix D: Oxygen-Hydrogen Isotopes	169
Appendix E: LA-ICP-MS Zircon Trace Elements.....	170
Appendix F: Whole Rock Geochemistry	174

List of Figures

Figure 2.1: Simplified map of the Michipicoten Greenstone Belt.....	7
Figure 2.2: Simplified geologic map of the area surrounding Island Gold.	8
Figure 3.1: Compiled dates and weighted mean ages of the three secondary standards, DD85 (A), DD91 (B), and Plesovice (C).	19
Figure 4.1: Leapfrog 3D rendering of main ore zones at Island Gold and the location of sampled drill core.	24
Figure 4.2: Simplified underground map of Island Gold showing mine infrastructure and domains.	25
Figure 4.3: Whole-rock geochemical classification schemes.	27
Figure 4.4: Outcrop photo (A) and hand sample photo (B) of sample 628.	29
Figure 4.5: Carbonatite classification diagram modified from Le Bas and Streckeisen (1991)...	29
Figure 4.6: Alteration level discrimination of all samples after Ciufo (2019).....	30
Figure 4.7: Thin sections photos of each alteration level.	33
Figure 4.8: Thin section pictures of sample 261 (A and B) and 623 (C).....	35
Figure 4.9: Kernel density estimate plot of all zircon grains analyzed from all samples.	39
Figure 4.10: CL images of 9 zircon grains analysed from sample 602..	41
Figure 4.11: CL images of 10 representative zircon grains analysed from sample 607.....	42
Figure 4.12: CL images of 13 representative zircon grains analysed from sample 608.....	43
Figure 4.13: CL images of 8 representative zircon grains analysed from sample 611.....	44
Figure 4.14: Concordia and weighted mean diagrams of samples 602, 607, 608, and 611.....	45
Figure 4.15: CL images of 16 representative zircon grains analysed from sample 612.....	46
Figure 4.16: CL images of 14 representative zircon grains analysed from sample 613.....	47
Figure 4.17: CL images of 15 representative zircon grains analysed from sample 614.....	48
Figure 4.18: CL images of 14 representative zircon grains analysed from sample 615.....	49
Figure 4.19: Concordia and weighted mean diagrams of samples 612, 613, 6014, and 615.....	50
Figure 4.20: CL images of 14 representative zircon grains analysed from sample 616.....	51
Figure 4.21: CL images of 26 representative zircon grains analysed from sample 620.....	52
Figure 4.22: Concordia and weighted mean diagrams of samples 616 and 620.....	53
Figure 4.23: Compilation of all dates from the protolith-aged populations.	54
Figure 4.24: CL images of 7 representative zircon grains analysed from sample 622, Group 1 (red labels) and 7 spots from Group 2 (blue labels).....	56
Figure 4.25: CL images of 7 representative zircon grains analysed from sample 622, Group 1 (red labels) and 10 grains from Group 2 (blue labels)..	57

Figure 4.26: Concordia and weighted mean diagrams of samples 622 and 260.....	58
Figure 4.27: CL images of 6 zircon grains from sample 261, Group 1 (red labels) and 9 zircons from Group 2.....	60
Figure 4.28: CL images of all 7 zircon grains analysed from sample 263, Group 1 (red labels) and 8 spots from Group 2 (blue labels).....	61
Figure 4.29: CL images of 12 zircon grains analysed from sample 264, Group 1 (red labels) and 8 grains from Group 2 (blue labels).....	63
Figure 4.30: CL images of 6 zircon grains analysed from sample 266, Group 1 (red labels) and 6 from Group 2 (blue labels).....	65
Figure 4.31: Concordia and weighted mean diagrams of samples 261, 263, 264, and 266.....	66
Figure 4.32: CL images of 12 zircon grains analysed from sample 262.	67
Figure 4.33: Tera-Wasserburg concordia diagram and $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean diagram for sample 262.	68
Figure 4.34: CL images of all 3 zircon grains analysed from sample 266, Group 1 (red labels, 4 analysis spots total) and 10 from Group 2 (blue labels)..	69
Figure 4.35: Tera-Wasserburg concordia diagram and weighted mean diagram for sample 628 Groups 1 and 2.	70
Figure 4.36: CL images of 16 representative zircon grains analysed from sample 621, the protolith-aged population of grains.....	72
Figure 4.37: Tera-Wasserburg concordia plot and $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age diagram for sample 621 with approximate weighted mean, protolith age population..	73
Figure 4.38: Wetherill concordia diagrams of zircon analyses 602-11, 622-15, and analyses from TY-128.	75
Figure 4.39: Wetherill Concordia diagram of all post-Archean analyses from sample 621.....	76
Figure 4.40: CL images of post-Archean zircon grains 602-11 and 622-15 (noted in blue) with approximate $^{206}\text{Pb}/^{238}\text{U}$ dates..	78
Figure 4.41: Cathodoluminescence images of 14/31 analyses of zircons that give post-Archean dates from sample 621, with approximate $^{206}\text{Pb}/^{238}\text{U}$ dates.....	79
Figure 4.42: Cathodoluminescence images of 17/31 analyses of zircons that give post-Archean dates from sample 621 with approximate $^{206}\text{Pb}/^{238}\text{U}$ dates.....	80
Figure 4.43: Wetherill Concordia diagrams of 18/31 post-Archean dates. $^{206}\text{Pb}/^{238}\text{U}$ dates range from circa 1138 Ma to 509 Ma on these diagrams.	81
Figure 4.44 Wetherill Concordia diagrams of 13/31 post-Archean dates. $^{206}\text{Pb}/^{238}\text{U}$ dates range from circa 392 Ma to 102 Ma on these diagrams..	82
Figure 4.45: Major element oxides (wt%) vs K ₂ O (wt%) for the age set classification.....	84
Figure 4.46: Major element oxides (wt%) vs K ₂ O (wt%) for the vein type classification.	85

Figure 4.47: Chondrite-normalized rare earth element diagram for samples classified by age group.	86
Figure 4.48: Chondrite-normalized rare earth element diagram for samples classified by vein type.....	86
Figure 4.49: $\delta^2\text{H}$ vs $\delta^{18}\text{O}$ fluid source discrimination plot, modified after Sheppard (1986).	87
Figure 4.50: $\delta^{34}\text{S}$ isotopes for 15 samples collected in this study compared to $\delta^{34}\text{S}$ isotopes of Ciufo (2019) (grey circles), to sample 621 (empty red square), and to TY128 (Ciufo (2019) sample containing Proterozoic zircons, solid red square).	88
Figure 4.51: Zircon trace element concentrations (in ppm) of Y, Nb, Hf, Pb, Th, and U vs age of the zircon grain (in Ma).	90
Figure 4.52: HREE chondrite-normalized plot of protolith-aged zircons (red field), sample 622 Group 2 (teal circles) and sample 628 Group 2 (red crosses) zircons.	91
Figure 4.53: Trace element concentrations of sample 628 Groups 1 and 2, and a selection of protolith-aged grains.	92
Figure 4.54: Trace element concentrations (in ppm) of individual zircon grains vs their dates...	94
Figure 4.55: U (ppm) vs zircon dates in post-Archean zircon grains and protolith-aged grains..	95
Figure 4.56: HREE plot of all 621 post-Archean zircons (lines and points) compared to 621 protolith zircon HREEs (shaded red area).	96
Figure 5.1: Simplified zoomed in map of the Superior Province with terranes outlines.....	112
Figure A.1: Secondary reference material DD85; Tera-Wasserburg concordia plots with weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ ages, number of zircons analysed (n), and MSWD from each analysis session.	128
Figure A.2: Secondary reference material DD91; Tera-Wasserburg concordia plots with weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ ages, number of zircons analysed (n), and MSWD from each analysis session.	129
Figure A.3: Secondary reference material Plesovice; Wetherill concordia plots with weighted mean $^{206}\text{Pb}/^{238}\text{U}$ ages, number of zircons analysed (n), and MSWD from each analysis session.	130

List of Tables

Table 4.1: Sample characteristics summary. Sample number, type, general location, alteration level, and associated vein type are listed.	22
Table 4.2: Summary of samples analysed for geochronology. Sample name, alteration level, number of zircons analysed, and $^{207}\text{Pb}/^{206}\text{Pb}$ age are included.	37
Table 4.3: Protolith-aged samples, ordered according to alteration level, detailing $^{207}\text{Pb}/^{206}\text{Pb}$ average dates and date ranges.	40
Table 4.4: $^{206}\text{Pb}/^{238}\text{U}$ dates of five zircons from sample TY128 of Ciufo (2019).	74
Table 4.5: Summary of dates for all post-Archean zircon analyses from sample 621, organized oldest to youngest. Dates are given Ma and the corresponding 2σ error for each is given to the right of each date column. Concordance percentage values ($^{206}\text{Pb}/^{238}\text{U}$ vs $^{207}\text{Pb}/^{235}\text{U}$ dates) for each date are given.	77

1.0 Introduction

Orogenic gold deposits are a major source of gold for society as a whole, accounting for ~75% of all gold mined throughout human history (Gaboury, 2019). As such a vital source, it is important to understand not only how these deposits form, but also how they may be enriched or depleted by external post-mineralization geological events. This thesis examines the Island Gold mine, a high-grade orogenic gold deposit in northern Ontario to explore the possibility of late fluid ingress into the deposit and elucidate the potential impact of a late fluid event on the gold distribution and grade.

The Island Gold mine is located within the Michipicoten Greenstone Belt in the Superior Province of Canada. Mineralization at Island Gold mine is dated to be between 2680–2673 Ma (Jellicoe et al., 2022), however, anomalous zircon rims from auriferous alteration zones, dated between ~1500 – 975 Ma were discovered (Ciufo, 2019). These dates are absent in the unaltered and unmineralized rocks. This suggests that the Island Gold mine underwent post-mineralization hydrothermal activity during the Proterozoic. This thesis will characterize Proterozoic fluid activity at Island Gold, including constraining timing of hydrothermal activity and composition and potential source of the fluid. This information will be used to propose an origin for these fluids, as the southern Superior Province has been impacted by several Proterozoic geological events such as the Mid-Continent Rift and the Kapuskasing Uplift (Percival et al., 2012). In addition, the information obtained during this study can be used in the future to determine if gold remobilization was possible, for example if downgrading or upgrading of gold grade or gold remobilization has occurred.

2.0 Background

2.1 Orogenic Gold Deposits

Orogenic gold deposits are found on every continent and range from Archean to Phanerozoic in age (Goldfarb and Groves, 2015). They form syn-tectonically in compressional or transpressional environments, typically at convergent plate margins (Groves et al., 1998). Orogenic gold deposits worldwide share several characteristics in addition to their spatial correlation with major collisional structures: 1) form between 5 and 15 km depth; 2) are structurally hosted by deformed metamorphic rocks; 3) mineralization is syn-metamorphic, occurring during post-peak metamorphism; 4) form at or above the brittle–ductile transition; 5) mineralizing fluid with a neutral to slightly alkaline pH, low to moderate salinity, and is aqueous-carbonic; and 6) alteration associated with elevated concentrations of S, K, Si, H₂O, CO₂ and Au, with negligible introduction of base metals (Goldfarb and Groves, 2015; Phillips and Powell, 2010; Tomkins, 2013).

The source of the auriferous fluids involved in orogenic gold deposit formation is a debated topic. Suggested fluid sources include magmatic fluids sourced from granitic intrusion and the circulation of meteoric waters, but fluids derived from metamorphic devolatilization during the transition from greenschist to amphibolite facies is generally favoured (Groves et al., 2018). Regardless of which fluid source is preferred, the importance of the characteristics of the fluid and the structural conduits in the genesis of orogenic gold deposits is widely acknowledged (Gaboury, 2019). Gold solubility is strongly impacted by both the pH and the oxygen fugacity of the fluid, and therefore these conditions also control the precipitation of gold (Williams-Jones et al., 2009). In addition, suitable ligands must be present within the fluid for gold to complex with, as gold alone is not soluble. The preferred ligand for Au⁺¹ ions is HS⁻ (reduced form of sulfur) as it has a Pauling unit >2.5 and will therefore preferentially form covalent bonds with HS⁻ over

ionic bonds with Cl⁻, the other main ligand in hydrothermal gold mineralization systems (Gaboury, 2019). Changes in oxygen fugacity, pH of the fluid, or a reduction in the activity of HS⁻ will result in gold precipitation (Gaboury, 2019). These changes can be facilitated by many processes, including fluid–rock interaction, decrease in temperature or pressure, boiling, or fluid mixing (Tomkins, 2013).

The auriferous fluids must travel from the source region along structural conduits and be concentrated into a depositional zone in order to form an economically viable deposit. Due to this, most orogenic gold deposits are found associated with major regional structures but are often hosted within second or third order structures (Phillips and Powell, 2010). Mineralization is hosted within such a wide range of structural types, such as high-angle reverse faults, low-angle thrust faults, saddle-reef dilatational zones, and normal faults, that there does not appear to be any structural feature(s) that is the most ideal for hosting orogenic gold. This characteristic is part of what makes orogenic gold deposits so diverse (Gaboury, 2019).

2.2 Regional Geology

The Island Gold deposit is located within the Michipicoten greenstone belt in the Wawa terrane of the Superior Province. The Superior Province is an Archean craton comprised of nine terranes delineated by changes in lithology and are bound by tectonic features that trend predominantly east-west, except in the north-eastern Superior Province where they trend generally northwest (Percival et al., 2012) (inset, Figure 2.1). The tectonic mechanisms involved in the formation of the Superior Province is a highly debated topic within the scientific community. It is generally accepted that there was some form of accretionary horizontal plate movement, however whether this horizontal movement was caused by modern-style plate tectonics involving subduction (Percival et al., 2012) or by a subduction-less style of horizontal

movement coupled with plume-controlled vertical tectonics (Bédard et al., 2013) is not agreed upon (Lodge, 2016). Despite the debate on the driving mechanisms, it is believed that the North Caribou superterrane (3.7 Ga) was the stable proto-cratonic block onto which all other terranes accreted between 2.72 and 2.68 Ga. Accretion began with the northern terranes of the Superior Province and progressed steadily southward (Percival, 2007) until cratonization occurred from 2680–2600 Ma (Percival et al., 2012).

Although the nature of the tectonic activity during the formation of the Superior Province is debated, it is widely accepted that it has been predominantly stable since 2.68 Ga, with only a few Proterozoic events impacting the interior of the craton (see Section 5.2.3) (Card, 1990; Percival et al., 2012). The margins, however, have been subject to Proterozoic orogenic events which now form the borders of the Superior Province (Percival and West, 1994).

The Wawa terrane is in the southern Superior Province and was one of the final terranes to be accreted to the craton in the Shebandowanian Orogeny at circa 2690 Ma (Percival et al., 2012). The Wawa terrane is often grouped with Abitibi terrane (located adjacent, to the east) into the Wawa-Abitibi terrane based on their similar lithologies and ages of plutonic, volcanic, and tectonic events (Percival et al., 2012); however, there are some differences between the two terranes (Mole et al., 2021) that make this link more tenuous. Considering the potential differences, the Wawa and Abitibi terranes are treated in this thesis as separate terranes.

The Wawa terrane extends N-S from the Quetico belt to the Southern Province and Midcontinent Rift, and E-W from the Vermilion district in Minnesota to the Kapuskasing Structural Zone (KSZ) (Figure 2.1, inset) (Card, 1990). It is comprised of supracrustal metavolcanic and metasedimentary domains metamorphosed to greenschist-amphibolite facies and plutonic granitoid and tonalitic gneiss (Percival and West, 1994). There are two groups of

greenstone belts, one in the north and one in the south (Polat, 2009)), between which are tonalite to granodiorite plutonic rocks that have been metamorphosed to amphibolite facies, with some intrusions of more potassic granitic units (Moser, 1994; Williams et al., 1991).

The Michipicoten Greenstone Belt (MGB) is part of the southern group of greenstone belts, and spans ~140 km in length and ~45 km in width, with east–west trending belts of supracrustal metavolcanic and metasedimentary units that are intruded by granitic plutons (Turek et al., 1982; Williams et al., 1991). The metavolcanic units are bimodal mafic to felsic with rare intermediate units (Sage et al., 1996) and are overlain by chemical sediments (e.g. iron formations) and by the Doré metasedimentary unit (Rice and Donaldson, 1992). All of these supracrustal rocks are metamorphosed at greenschist facies.

The metavolcanic rocks were extruded in three discrete episodes; the Hawk Lake assemblage is dated at ~2889 Ma, the Wawa assemblage at ~2750 Ma and the Catfish assemblage at ~2700 Ma (Williams et al., 1991). The mafic units of the Hawk Lake assemblage range from basaltic to komatiitic in composition while the mafic units of the Wawa assemblage and the Catfish assemblage show slightly more evolved geochemistry and are tholeiitic in composition (Heather and Arias, 1992). The basalts of all three cycles are believed to be sourced from a mantle plume (asthenospheric origin) with minor continental crust contamination (Sage et al., 1996). The felsic portions of all three bimodal units are calc-alkaline dacites and rhyolites (Heather and Arias, 1992) and may have formed from either re-melted continental crust or extensive continental crust contamination of a mantle-derived evolved melt. Contacts between all three cycles are highly strained, and therefore the contacts are not considered primary. Both the Hawk Lake and Wawa assemblages are overlain by chemical sedimentary units, and the Wawa assemblage is capped by the Michipicoten Iron Formation (Williams et al., 1991).

The metavolcanic and metasedimentary units are intruded by a number of plutons that range in composition including trondhjemite, syenite, and diorite-gabbro complexes (Turek et al., 1984). These complexes also range in age, some are syn-volcanic with each of the volcanic assemblages (e.g., 2888 Ma Hawk Lake Granitic Complex, 2745 Ma Jubilee Lake Stock), some are pre-tectonic (e.g. ~2722 Ma Gutscher Lake Stock trondhjemite), and some are late- to post-tectonic (e.g. 2671 ± 2 Ma Troupe Lake Stock, quartz-monzonite granodiorite) (Sage et al., 1996).

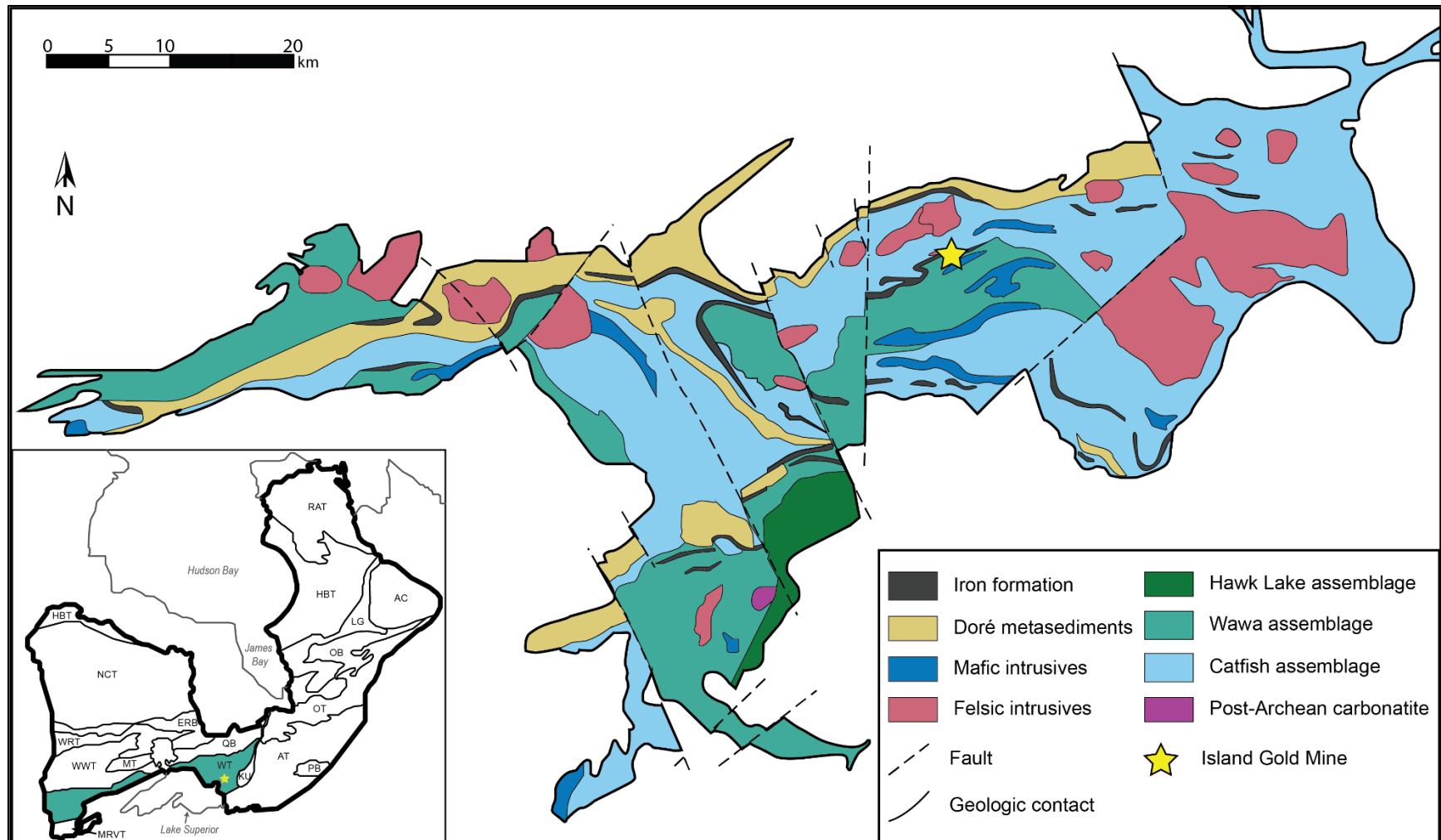


Figure 2.1: Simplified map of the Michipicoten Greenstone Belt (modified from Williams et al., 1991). Island Gold is denoted with a yellow star. Inset map is a simplified map of the Superior Province (modified from Percival et al., 2012) emphasizing the Wawa terrane (in green) and the location of the MGB (yellow star).

2.3 Island Gold Geology

The Island Gold Mine is located in the northern MGB, within the felsic-intermediate upper metavolcanic rocks of the Wawa assemblage, on the northern limb of the Goudreau Anticline (Figure 2.1) (Bourgeault et al., 2022). Mineralization is hosted within the Goudreau Lake Deformation Zone (GLDZ), a regional brittle–ductile deformation structure that is considered to be the structural control on gold mineralization in the area (Bourgeault et al., 2022; Jellicoe et al., 2022). The GLDZ is an oblique-slip fault zone that trends north-east and is ~30 km long and ~4.5 km wide and extends across the contact between the felsic units of the Wawa assemblage and the lower mafic units of the Catfish assemblage (Heather and Arias, 1992).

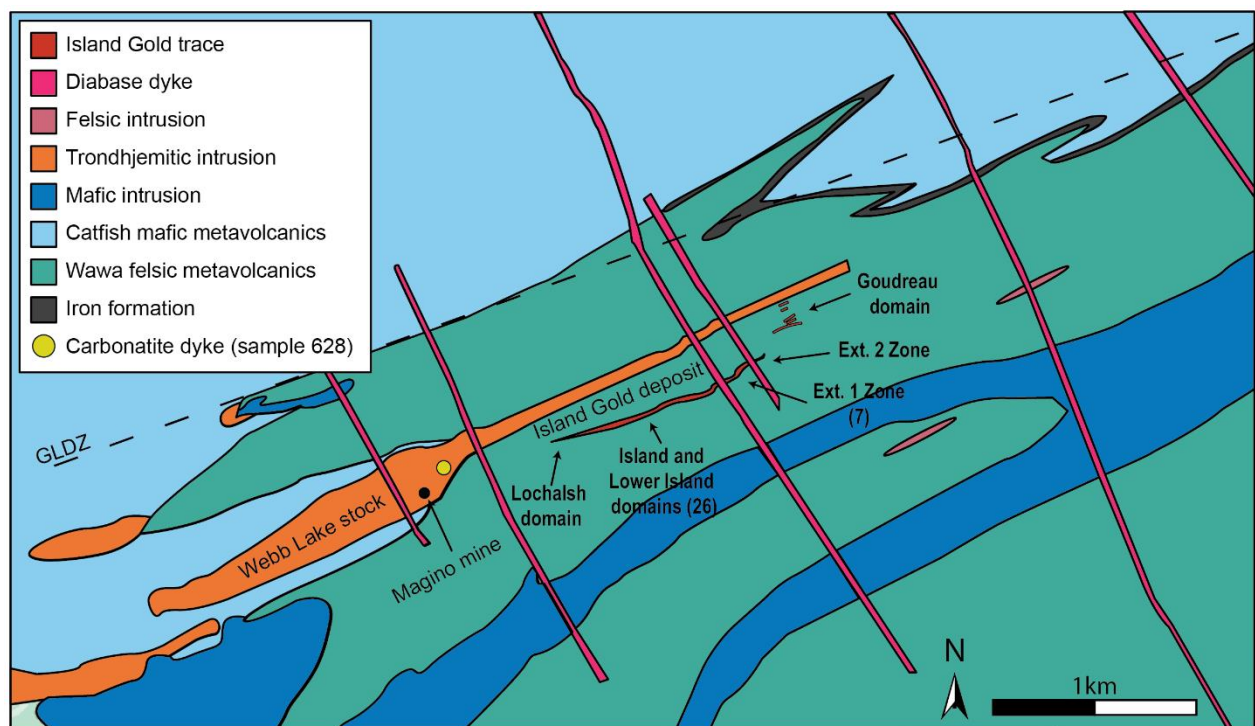


Figure 2.2: Simplified geologic map of the area surrounding Island Gold. Delineations of the Island Gold deposit are labelled, and number of samples collected from each area are included. Yellow point indicates location of a carbonatite dyke that was sampled in this study (sample 628). Modified from Jellicoe, 2019.

Three deformation events occurred at Island Gold (Jellicoe et al., 2018). D₁ is a regional N-S compressional event that created regional folds (ex. Goudreau Anticline), and is when several felsic intrusions were emplaced, including the Webb Lake stock and the Gutcher Lake

Stock. D₂ is a northside-up sinistral transpressional event that resulted in the formation of the GLDZ, and the regional greenschist metamorphism and associated S₂ foliation. D₃ is a dextral southside-up transpressional event that resulted in F₃ folds and S₃ foliation that partially overprints previous structures (Jellicoe et al., 2018). Mineralization at Island Gold is considered to be contemporaneous with D₂, both of which have been constrained to ~2680–2672 Ma, based on U/Pb zircon geochronology of a mineralized, foliated pre-D₂ pluton (Webb Lake stock) and an unmineralized, unfoliated dyke that crosscuts foliation and mineralization within the deposit (Jellicoe et al., 2022).

The Island Gold deposit is hosted primarily within felsic-intermediate metavolcanic rocks that range in texture from massive to volcanoclastic (Jellicoe et al., 2022). The protolith is unclear, however Ciufo (2019) suggests that it is dacite based on geochemical classification and mineral compositions and textures within the least-altered samples. The altered nature of the samples prevents further classification, therefore for consistency, I will refer to these rocks as dacites, but acknowledge that they may originally have been intrusive in origin but are now overprinted by pervasive alteration. Minor mineralization is hosted within gabbro and diabase intrusions that crosscut the volcanic packages, but which are metamorphosed to greenschist facies and display S₂ foliation. The host rock is altered in the ore zones, characterized by strong silicification and an increase in biotite, chlorite, white mica, and carbonate, as well as an enrichment in K₂O, Rb, S, and Te and a depletion in Na₂O (Ciufo et al., 2019).

Mineralization is present as east-northeast striking and steeply south-dipping sub-parallel quartz-veins that are parallel to S₂ foliation. The deposit is comprised of five domains: the Lochalsh domain, the Upper Island domain, the Lower Island domain, the Eastern domain (Extension 1 and Extension 2 zones), and the Goudreau domain (Figure 2.2) (Bourgeault et al.,

2022). The delineation between the Upper Island domain and the Lower Island domain is a flexure point at ~500m where the ore zones dip shallows slightly and then steepens again for the remainder of the deposit. All samples in this thesis were collected from the Lower Island Domain and the Eastern domain (Extension 1 specifically).

Five vein types are present at Island Gold, three of which are gold-bearing. V₁ veins are 10-40cm thick laminated quartz shear veins that are steeply dipping and sub-parallel to the ore zones and host the majority of mineralization. They are characterized by bands of quartz and minor sericite, chlorite, and pyrite that alternate with bands of strongly altered host rock. These veins range from smoky grey to milky white in appearance (Jellicoe et al., 2022). V₂ veins are millimeter to centimeter scale crack-seal veinlets subparallel to S₂ foliation and to V₁ veins. They are composed of fine-grained quartz, sericite, chlorite, and pyrite, and minor gold. V₁ and V₂ veins are considered contemporaneous and are spatially associated, so they will be referred together in this thesis as “V₁-V₂” veins.

V₃ veins are primarily barren and uncommonly weakly mineralized (Bourgeault et al., 2022). They are composed of quartz and carbonate and occur as boudin necks in boudinaged V₁ veins, as en echelon veins, and as extensional veinlets that crosscut V₁ veins. They are interpreted to have been emplaced during D₃ (Jellicoe et al., 2022).

V₄ veins are barren tourmaline veins that crosscut all veins and structures. They occur as cores within other veins and occur parallel along the margins of other veins, as ribbons that crosscut previous veins, as thin sheets and as blocky masses. These veins were emplaced post-mineralization, as they also crosscut unmineralized monzodiorite intrusions within the deposit (Jellicoe et al., 2022).

V_{GD} veins are found only within the Goudreau Domain, are quartz-carbonate extensional veinlets commonly with tourmaline cores and were likely emplaced during D₂ (Jellicoe et al., 2022). As these veins are not found within the study area of this thesis, they will not be discussed further.

3.0 Methods

3.1 Overview

Thirty-three samples were collected; thirty-two samples are dacite (main host rock) and have been variably altered by auriferous quartz ($\pm$ carbonate) veining. Drill core samples (18 samples; 601-618) range from least altered to strongly altered and underground samples (14 samples; 619-625, 260-266) are moderately to strongly altered. One sample (628) is a carbonatite that outcrops on the surface to the west of the mine site (see Section 0 for classification). This sample is the inferred equivalent of the carbonatite dykes found underground at the Island Gold mine.

All samples were made into polished thin sections to evaluate mineral compositions and textures (Section 3.2) and were analyzed for major and trace element whole-rock geochemistry (Section 3.3.3), oxygen-hydrogen isotopes (Section 3.5), and sulfur isotopes (Section 3.6). All samples were crushed and processed for zircon separation for U/Pb geochronology (Section 3.3.1) and zircon trace element analysis (Section 3.3.2).

3.2 Petrography

Thin section billets were cut at the University of Waterloo and sent to Vancouver Petrographics Ltd. (samples 601-625) and Precision Petrographics Ltd. (samples 260-266) for polished thin section creation, which allow for transmitted and reflected light petrography.

3.3 LA-ICP-MS

Zircon separates were obtained through two methods. Samples 601-625 were sent to Overburden Drilling Management, where samples were crushed, disaggregated with electrical pulse, and the -1.0mm fraction was further separated using a shaking table and manual panning for zircon. Samples 260-266 and 628 were crushed at Western University (Earth Sciences

Department), then sieved to a $-300\mu\text{m}$ fraction, on which magnetic separation (Frantz Isodynamic magnetic separator) and heavy liquid separation (methyl iodide, 3.22g/cm^3) were performed to isolate the heavy minerals. Zircons were manually picked and mounted in epoxy resin pucks that were polished and imaged with cathodoluminescence (CL). CL imaging was performed at WATlabs at the University of Waterloo on the Zeiss Leo 1530 FESEM equipped with a Deben Centaurus CL monochromatic detector to image internal zonation of the zircon grains.

Zircon mineral separates were imaged using CL to locate dark, thin rims and indistinct zonation, similar to the Proterozoic rims found in Ciufo (2019); these domains are distinct in CL to the zircons with oscillatory or planar zoning that yield Archean ages. These dark rims, as well as lighter-coloured rims, and selected cores were analyzed for U/Pb isotope ratios (for date determination) and for trace element compositions (to ascertain fluid composition differences) using an Analyte G2 laser ablation system coupled to a triple quadrupole inductively-coupled-plasma mass spectrometer (Agilent 8800 and Nu Plasma 2) in the Metal Isotope Geochemistry Laboratory at the University of Waterloo.

Initially, U/Pb isotopes and trace elements were analyzed simultaneously via split-stream analysis in order to directly link the age with trace element information of the ablated rim. However, this was ineffective considering the paucity of Proterozoic rims and the narrow width of the rims. Subsequent analyses, comprising the entirety of data included in this thesis, focus on single-stream acquisition of U/Pb isotopes on a Nu Plasma 2 followed by single-stream trace element analysis on an Agilent 8800.

3.3.1 Geochronology Analytical Parameters

Analytical parameters for zircon polished epoxy puck laser ablation varied slightly between analysis sessions as the ablation method was refined. Three analysis sessions were conducted: December 2021, June 2022 (10th, 13th, and 14th), and October 2022. The December 2021 analysis session was single-stream analysis to the Nu Plasma 2, with a laser ablation spot size of 20µm, a laser repetition rate of 8 Hz, a laser fluence of 2 J/cm² (measured at the sample surface), an ablation time of 20s, and a gas background acquisition time of 30s between analyses. The June 2022 and October 2022 analysis sessions used many of the same parameters, except a spot size of 12µm was used, with 25s of background between each spot. Carrier gas was 0.6 L/min helium gas with 0.8 L/min of argon. ²³⁸U and ²³²Th were collected on Faraday collectors (H10, H8) and Pb isotopes (²⁰⁸Pb, ²⁰⁷Pb, ²⁰⁶Pb) were collected on ion counters (IC0, IC1, IC2). Integration times were 0.1s. For reference materials, a sample standard bracketing method was employed. Analyzed reference materials were NIST612 (glass standard), DD85-17 (Tomlinson et al., 2003), DD91-1 (Davis, 2002), Plesovice (Sláma et al., 2008), and 91500 (Wiedenbeck et al., 1995) (natural zircon standards).

U–Pb geochronology data was corrected for instrumental mass fractionation (laser and plasma) using the most appropriate matrix-matched reference material, in this case the natural zircon standard 91500 (low U standard). Data was processed using the Iolite (v4) software package (Paton et al., 2011) that also corrects for downhole fractionation using the U-Pb data reduction scheme. Various reference materials were analyzed, some for primary standards (to correct for instrumental mass fractionation) and others for secondary standards (to assess data accuracy).

Individual data points were omitted from weighted mean age calculations based on the consideration of several factors. These factors were: quality of time-resolved $^{207}\text{Pb}/^{206}\text{Pb}$ or $^{238}\text{U}/^{206}\text{Pb}$ ratios after data processing (non-flat ratios indicate mixed age domains, and were omitted), or if the raw ablation pattern was highly irregular, indicating analytical artifacts such as drill throughs or inclusions. Any combination of these factors resulted in the omission of that zircon analysis from further consideration. All ratios ($^{207}\text{Pb}/^{235}\text{U}$, $^{206}\text{Pb}/^{238}\text{U}$, and $^{207}\text{Pb}/^{206}\text{Pb}$) and calculated ages for all individual analyses, including those omitted from weighted mean age calculations and concordia plots, can be found in Appendix B. Although weighted means were calculated, they do not represent a single statistical mean due to the precise yet scattered nature of the data, and therefore are reported as averages (see Section 5.2 for a more detailed discussion). Discordance of selected zircon grains (Section 4.2.4.2) was calculated using the following equation: discordance = $1 - (^{206}\text{Pb}-^{238}\text{U} \text{ date} / ^{207}\text{Pb}-^{235}\text{U} \text{ date})$ (Vermeesch, 2021).

3.3.2 Trace Elements Analytical Parameters

Trace element analysis spots were selected based on U/Pb dates of zircons. A suite of protolith-aged zircons (from samples 621 and 622), sample 622 zircons dated between ~2650 – 2620 Ma zircons, carbonatite zircons (samples 628-Groups 1 and 2), and all post-Archean zircons from sample 621 were analyzed for trace elements to enable comparison between the different age groups.

Isotopes of the following trace elements (^{29}Si , ^{43}Ca , ^{93}Nb , ^{51}V , ^{55}Mn , ^{88}Sr , ^{89}Y , ^{181}Ta , ^{178}Hf , ^{208}Pb , ^{232}Th , ^{238}U , ^{139}La , ^{140}Ce , ^{141}Pr , ^{144}Nd , ^{152}Sm , ^{153}Eu , ^{157}Gd , ^{159}Tb , ^{163}Dy , ^{165}Ho , ^{166}Er , ^{169}Tm , ^{173}Yb , ^{175}Lu) were collected on the Agilent 8800, with 10 ms integration times across two analysis sessions. For both sessions, the laser ablation spot size was 12 μm , laser repetition rate of 8 Hz, and an ablation time of 30s with a 30s blank between each analysis. For the first session

where all sample 621 grains (across all U-Pb dates) and sample 628-Group 1 grains were analysed, a laser fluence of 4 J/cm² (measured at sample surface) was used. For the second session, where zircons from samples 622 (Groups 1 and 2), sample 628-Group 2, and sample 616 were analyzed, a laser fluence of 2 J/ cm² (measured at sample surface) was used. The synthetic glass reference materials NIST 612 and NIST 610 were analyzed as well, as they are commonly used to correct for instrumental mass fractionation, and natural zircon standard 91500 was analysed as a secondary reference.

An internal standard approach (Chew et al., 2014) was employed to determine the concentrations of trace elements assuming a stoichiometric amount of Si in zircon (31.52 wt %, Deer et al., 1982). NIST 610 was used as the primary reference material to correct for instrumental mass fractionation. Data was reduced using the trace element data reduction scheme (internal standard) using the Iolite (v4) software package (Paton et al., 2011). Due to the small spot size used (and low signal), trace element accuracy was lower than anticipated (~50% difference from expected values for most trace elements). Therefore, trace element concentrations collected in this thesis are fit to compare to one another, however, should not be compared to other published material. Accuracy of the trace element concentrations in the secondary reference material were better than 50% for elements rare earth elements Tb through Lu, Y, Th, and U, better than 30% for Nb, and better than 10% for Hf. Rare earth elements La through Gd, Sr, Ta, Ca, Ti, V, Mn, and Zn were all below detection limit in the sample zircons and are therefore not included in this thesis.

3.3.3 Geochronology QA/QC

Samples were analyzed over 5 different sessions between December 2021 and October 2022. Four zircon standards were analyzed during each analysis session, one primary standard

(91500) and three secondary standards (DD85, DD91, and Plesovice). Figure 3.1 summarizes the individual $^{207}\text{Pb}/^{206}\text{Pb}$ ages for each zircon analysis for all three secondary standards, grouped by analysis session, and the weighted mean age for each session. For a detailed table of all isotope ratios and ages for individual analyses, see Appendix B.

A 12 μm spot was used for all analysis sessions except December 2021 when a 20 μm spot size was used. The 12 μm spot size is smaller than what is typically used in LA-ICP-MS geochronology (Mukherjee et al., 2019), but was used in this study due to the thin nature of zircon rims that were analyzed. A more detailed discussion of analytical uncertainties and sources of error associated with the use of small spot sizes can be found in Section 5.2, however the main points are summarized here. There are two analytical limitations of using a very small spot size. First, downhole fractionation of U from Pb (Paton et al., 2010) is amplified (see Section 5.2 for more detail). Therefore, $^{238}\text{U}/^{206}\text{Pb}$ ratios should be treated with some caution due to the unresolved influence of downhole fractionation. However, this is not expected to influence the $^{207}\text{Pb}/^{206}\text{Pb}$ ratio, which is used to calculate ages from Archean zircon populations (Mukherjee et al., 2019). Evidence for this is the reproducibility of $^{207}\text{Pb}/^{206}\text{Pb}$ dates of the secondary reference materials (Figure 3.1).

The second analytical issue is that the signal decreases substantially with depth due to a progressively smaller amount of material being ablated down hole. This has a particularly large effect on U—measured on a Faraday cup—where down-hole signal reduction brings the U signal close to background. At these low signals, appropriate corrections for downhole fractionation and instrumental mass fraction are not feasible. The reduced signal down hole is less of an issue for Pb isotopes, which are measured on ion counters that are much more sensitive (i.e. signal is usually well above the background). Data may plot off concordia (normal and reverse

discordance) due to these analytical artefacts. However, this analytical issue does not strongly influence the $^{207}\text{Pb}/^{206}\text{Pb}$ dates as verified by the reproducibility of the $^{207}\text{Pb}/^{206}\text{Pb}$ dates of the secondary reference materials.

The weighted mean ages for secondary reference materials DD85 and DD91 (Archean ages) for all analysis sessions are within +/- 1% of their accepted ages, and the weighted mean ages for Plesovice are offset from the accepted value by up to ~2%. The larger scatter on the Plesovice reference material is partly due to the relatively low amount of ^{207}Pb due to this being a Carboniferous reference material. In addition, this Plesovice reference material can contain very large concentrations of U (which are heterogenous in individual grains and between grains), which makes it more susceptible to enhanced downhole fractionation. Unresolved downhole fractionation would yield an older $^{238}\text{U}/^{206}\text{Pb}$ date than the accepted value, and this is observed in my dataset (Figure 3.1c). Considering the results of the secondary reference materials, the data from my samples are considered fit for the purpose of this thesis, which is evaluating if there are Proterozoic and Phanerozoic ages within an Archean deposit. Concordia plots of each reference material for each analysis session are summarized in Appendix A.

Dates older than ~1500 Ma are given as $^{207}\text{Pb}/^{206}\text{Pb}$ dates, while dates younger than 1500 Ma are given as $^{238}\text{U}/^{206}\text{Pb}$ dates. This is done because younger zircons will contain lower amounts of Pb, which will negatively impact the counting statistics of the Pb isotopes during analysis, making the $^{207}\text{Pb}/^{206}\text{Pb}$ ratios more imprecise than the $^{238}\text{U}/^{206}\text{Pb}$ ratios.

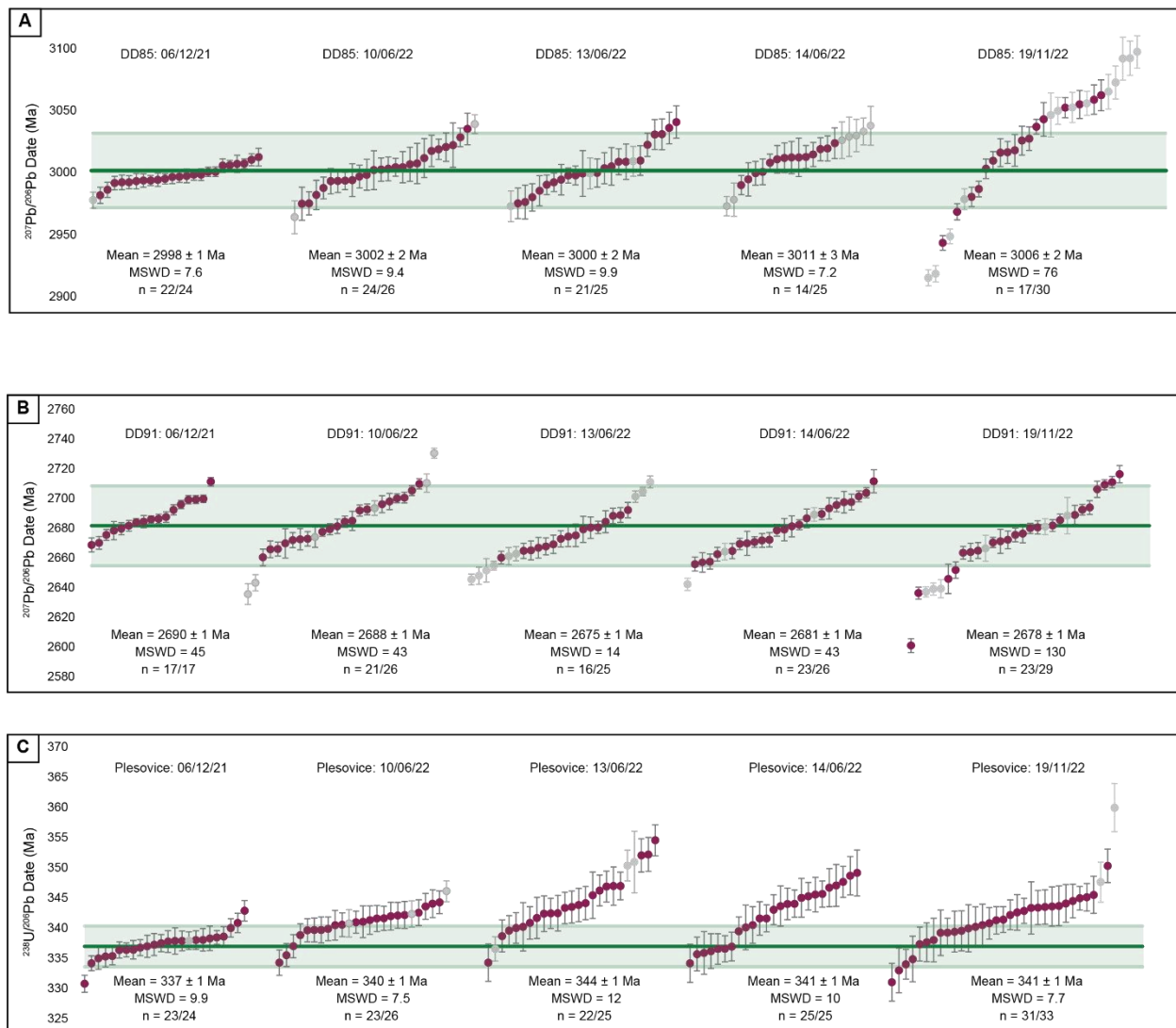


Figure 3.1: Compiled dates and weighted mean ages of the three secondary standards, DD85 (A), DD91 (B), and Plesovice (C). Individual points are individual grain dates; those in red are included in the weighted mean age calculation while those in grey are excluded from the weighted mean age calculation. Grains were excluded due to problems with ablation (low ^{238}U counts and drill-throughs). Green lines indicate the accepted age (in Ma) of each standard, light green bands indicate a $\pm 1\%$ range of the accepted age. DD85 and DD91 are $^{207}\text{Pb}/^{206}\text{Pb}$ dates and Plesovice is $^{238}\text{U}/^{206}\text{Pb}$ dates.

3.4 Whole Rock Geochemistry

Whole rock geochemistry was conducted at Activation Laboratories Ltd. The package 4E-Research + ICP-MS was selected for all samples; 10 major oxides and 41 trace elements were analyzed with this package. Samples underwent lithium metaborate/tetraborate fusion followed by nitric acid digestion and elements were analyzed on INAA, ICP-MS and ICP-OES,

with detection limits of 0.01% for all major oxides, and detection limits of 0.01ppm for most trace elements.

3.5 Oxygen-Hydrogen Isotopes

Oxygen-hydrogen (OH) isotope analysis was conducted on samples 601-625. Samples 601-625 were sent for OH isotopes at Queen's Facility for Isotope Research, Queen's University. Oxygen isotopes were analyzed using a Thermo-Finnigan Delta^{plus}XP Isotope-Ratio Mass Spectrometer with the BrF₅ procedure described in Clayton and Mayeda (1963). Oxygen isotopes are reported relative to the Vienna Standard Mean Ocean Water (VSMOW), with a precision of 0.4‰.

Hydrogen isotopes were analyzed using a MAT 253 Stable Isotope Ratio Mass Spectrometer coupled to a Thermo-Scientific TC/EA High Temperature Conversion Elemental Analyzer. Values are reported relative to VSMOW, with a precision of 3‰.

3.6 Sulfur Isotopes

Sulfur isotope analysis was conducted prior to the collection of samples 260-266 and 628, therefore sulfur isotopic analysis was conducted only on samples 601-625. Sixteen of these twenty-five samples contained sufficient concentrations of sulfur to allow for sulfur isotope analysis to be conducted. Samples 602, 603, 608, 609, 610, 613, 614, 617, 618, 619, 620, 621, 623, 624, 625, and T128 were analyzed at the Environmental Isotope Lab, University of Waterloo. Measurement of the ³⁴S isotope was conducted through combustion conversion of sample material to gas with a 4010 Elemental Analyzer coupled to an Isochrom continuous flow isotopes ratio mass spectrometer. Samples are mixed with a few mg of ground WO to aid with the conversion to SO₂ gas. $\delta^{34}\text{S}$ isotope values are relative to the primary reference material Vienna-Canyon Diablo Troilite meteorite (VCDT), with a precision of 0.3‰.

4.0 Results

This section outlines sample characteristics (location, type, mineralogy, alteration level), as well as results of zircon geochronology, zircon trace element analysis, whole-rock geochemistry, oxygen isotope, hydrogen isotope, and sulfur isotope analysis.

4.1 Sample Summary

Thirty-three samples were collected comprising drill core (18 samples), underground grab samples (14 samples), and one above-ground outcrop sample. Drill core samples consist of an altered and deformed dacite sampled across a range of alteration levels (least altered, weakly altered, moderately altered, and strongly altered) associated with auriferous veins, and grab samples range from moderately to strongly altered dacite adjacent to auriferous veins (see Section 4.1.1.1). All drill core samples are associated with V1-V2 veining and underground grab samples are associated primarily with V1-V2 veining; however, some contain cores of tourmaline stringers or are cross-cut by quartz-tourmaline veins, indicating infiltration by V4 veins. Table 4.1 summarizes key characteristics of all samples, including sample type, general location, alteration level, and associated vein type. Drill core samples from the same borehole are grouped by thick borders.

Table 4.1: Sample characteristics summary. Sample number, type, general location, alteration level, and associated vein type are listed.

Sample #	Sample Type	Location (depth m)	Alt. Level	Vein type
601	DC	Lower Island	Least	V1-V2
602	DC	Lower Island	Weak	V1-V2
603	DC	Lower Island	Strong	V1-V2
604	DC	Ext. 1	Least	V1-V2
605	DC	Lower Island	Least	V1-V2
606	DC	Lower Island	Weak	V1-V2
607	DC	Ext. 1	Least	V1-V2
608	DC	Ext. 1	Weak	V1-V2
609	DC	Ext. 1	Strong	V1-V2
610	DC	Ext. 1	Strong	V1-V2
611	DC	Lower Island	Strong	V1-V2
612	DC	Lower Island	Weak	V1-V2
613	DC	Lower Island	Moderate	V1-V2
614	DC	Lower Island	Strong	V1-V2
615	DC	Lower Island	Least	V1-V2
616	DC	Lower Island	Least	V1-V2
617	DC	Lower Island	Strong	V1-V2
618	DC	Lower Island	Strong	V1-V2
619	UG sample	Ext. 1 (620m)	Moderate	V1-V2, V4
620	UG sample	Ext. 1 (620m)	Strong	V1-V2
621	UG sample	Lower Island (770m)	Strong	V1-V2, V4
622	UG sample	Lower Island (770m)	Strong	V1-V2, V4
623	UG sample	Lower Island (880m)	Strong	V1-V2, diabase dyke (I3DD)
624	UG sample	Lower Island (880m)	Strong	V1-V2, V4
625	UG sample	Ext. 1 (880m)	Strong	V1-V2, V4
628	Outcrop sample	Surface outcrop	N/A (Carbonatite)	N/A (Carbonatite)
260	UG sample	Lower Island (785m)	Moderate	Barren N-S vein
261	UG sample	Lower Island (785m)	Strong	V1-V2, V3, V4
262	UG sample	Lower Island (850m)	Strong	V1-V2, V4
263	UG sample	Lower Island (850m)	Strong	V1-V2, V4
264	UG sample	Lower Island (770m)	Strong	V1-V2, V4
265	UG sample	Lower Island (770m)	Strong	V1-V2, V4
266	UG sample	Lower Island (750m)	Moderate	V1-V2, V4, N-S vein
TY128*	UG sample	Lower Island	Strong	V1-V2

DC = drill core, UG = underground.

*TY128 is a sample collected and analyzed by Ciufu (2019). Data for this sample is from Ciufu (2019).

Sample 261 is strongly altered dacite from a V1-V2 vein alteration envelope, however the V1-V2 vein is cross-cut by a V3 vein, and so the adjacent wall-rock may have been affected by this late vein (see Section 4.1.1.1). Sample 623 is from dacite wall rock adjacent to a mafic dyke; this area was sampled to assess if the emplacement of the mafic dyke impacted the wall rock, and therefore there are no veins associated with this sample. Sample 260 is associated with a barren north-south oriented quartz vein and was sampled to allow for comparison of geochemistry and geochronology with auriferous quartz veins. As this N-S vein does not have any cross-cutting relationships with documented vein types (i.e., V1, V2, etc.), it is unclear if this is a V3 vein or a different vein type. Sample 266 is dacite wall rock adjacent to a V1-V2 vein and an N-S oriented, barren, quartz-tourmaline vein. This N-S vein is ambiguous and not currently part of the vein classification system at Island gold.

The single above ground sample is a carbonatite dyke that outcrops at the surface west of the mine site (Figure 2.2). Carbonatite occurs both at surface and within underground drill core, and it is assumed that both occurrences are petrogenetically related.

Figure 4.1 and Figure 4.2 show locations of drill core and underground grab samples, respectively. All samples are below the 500m flexure point of the ore zones, and most are located within the Lower Island Domain and seven are from the East Domain (Extension 1).

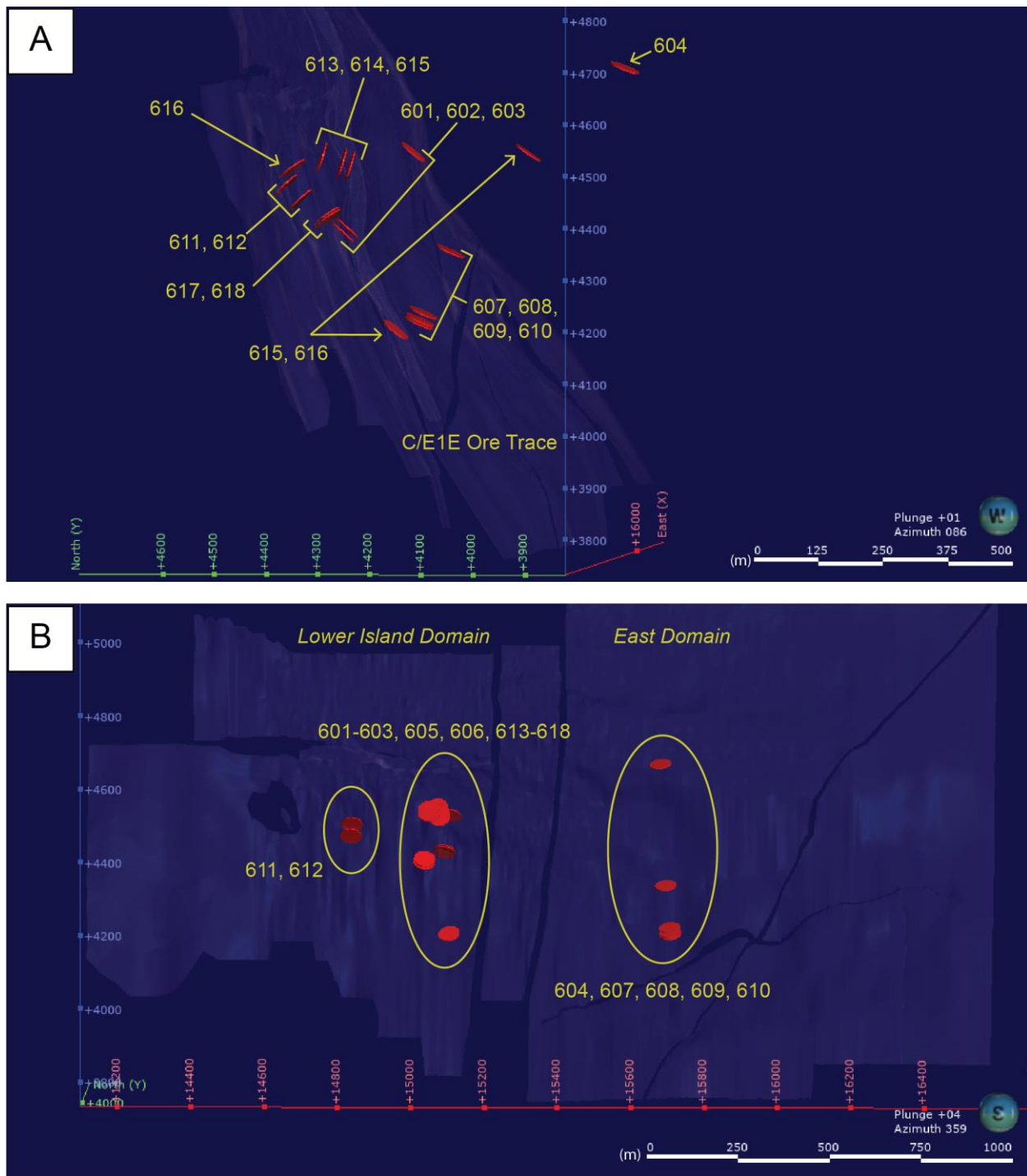


Figure 4.1: Leapfrog 3D rendering of main ore zones at Island Gold and the location of sampled drill core. A: view looking east across C/E1E ore trace with all drill core samples labelled to display relative distance from ore trace. B: view looking north to show lateral distribution of drill core across ore trace.

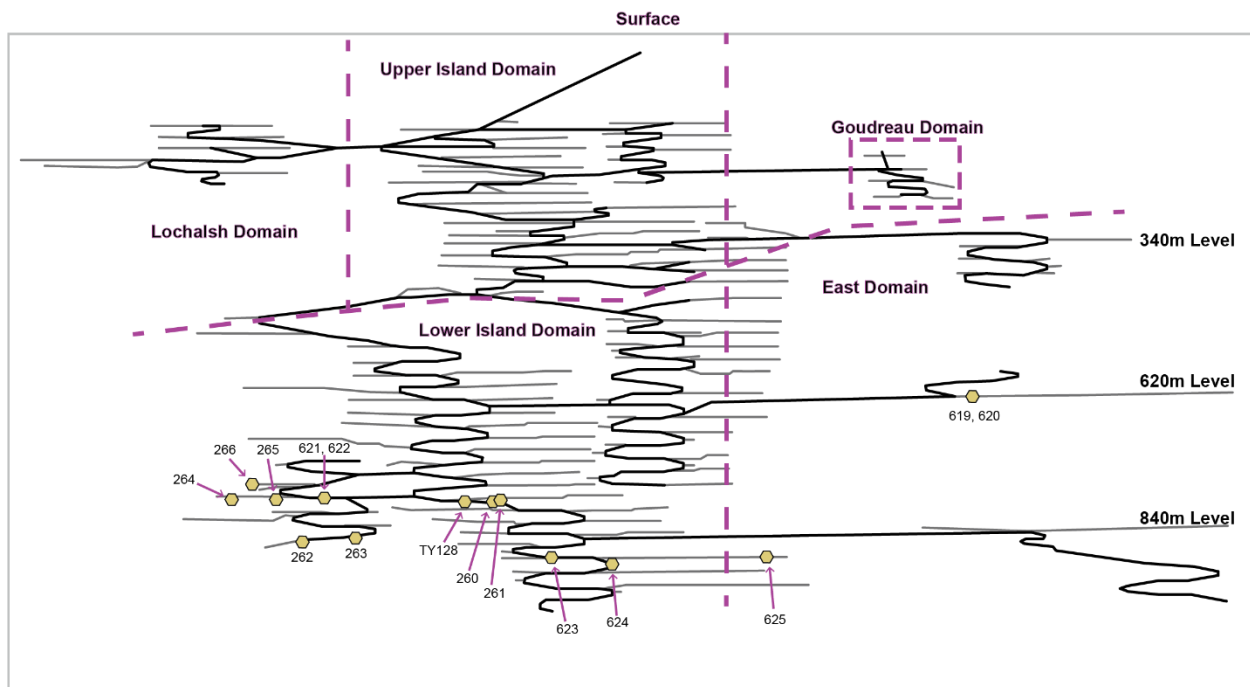


Figure 4.2: Simplified underground map of Island Gold showing mine infrastructure and domains. Underground grab sample locations are marked by yellow hexagons and labelled with sample numbers. Levels (right-hand side labels) indicate the depth from surface.

4.1.1 Sample Classification

Samples were classified using geochemical and petrographical analysis, following the rock unit classification completed by Ciufo (2019). Least altered samples (see Section 4.1.1.1 for alteration level discrimination) were used for classification and three classification schemes were employed: one using mobile elements and two using immobile elements. The mobile element scheme is the TAS (total alkali silica) diagram of Le Bas et al. (1986) (Figure 4.3, C) and the two immobile element schemes are Co vs Th of Hastie et al. (2007) and the Nb/Y vs Zr/Ti of Pearce (1996) (Figure 4.3, A and B respectively).

All samples plot within the andesite/basaltic andesite area of the Nb/Y and Zr/Ti diagram and all but one plot within the andesite/basaltic andesite field of the Co vs Th diagram, where one sample plots within the dacite/rhyolite field (Figure 4.3, A and B). All samples plot within the dacite field of the TAS mobile element diagram (Figure 4.3, C). This discrepancy between the immobile and mobile element schemes may be due to the greenschist metamorphism undergone by all samples, including the least altered samples. Regardless, these results correspond to the classification of “dacite” outlined by Ciufo (2019). In an effort to remain consistent with previously published literature, all samples in this thesis are classified as dacite at varying alteration levels (see Section 4.1.1.1). However, it is acknowledged that the immobile classification is likely more correct for a petrographic classification.

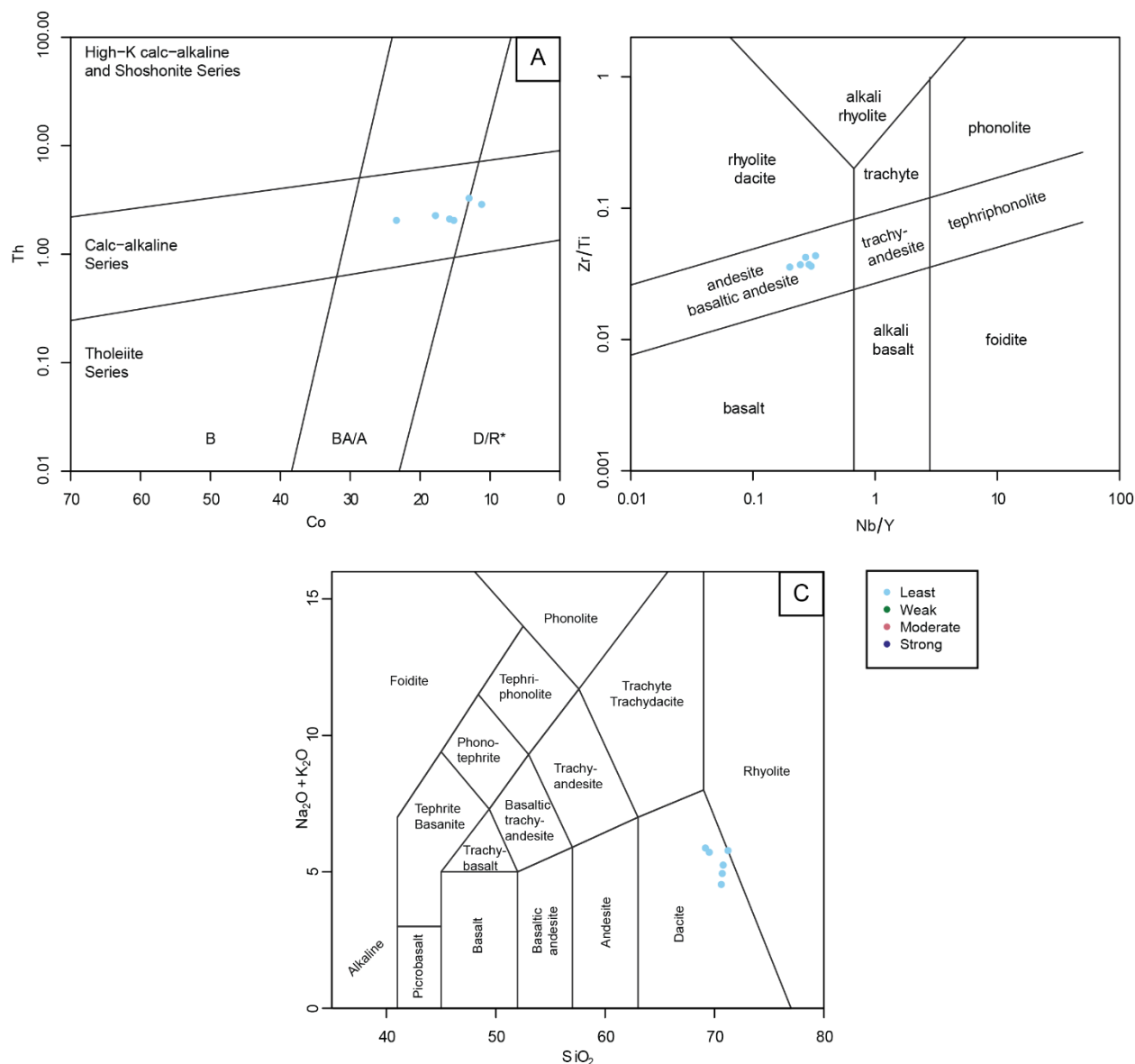


Figure 4.3: Whole-rock geochemical classification schemes. A: Co vs Th diagram (Hastie et al., 2007) using least altered samples. B: Nb/Y vs Zr/Ti diagram (modified from Pearce, 1996) using least samples. C: TAS diagram (Bas et al., 1986) using least altered samples.

Sample 628 was collected from a carbonatite dyke located west of Island Gold at 16U 0689070 N 5352981 E (Figure 2.2). The dyke displays a sharp contact with the host unit, likely the Webb Lake Stock, indicating that it was emplaced after the intrusion of the Webb Lake Stock (Figure 4.4, A).

Due to the friable nature of the sample, no thin section was made. However, hand samples were collected for geochemical analysis and macroscopic mineralogy and textural

observations. The sample is composed of ~90% carbonate minerals, ~3% biotite (subhedral, 0.5 – > 1 cm), ~5% magnetite (euhedral to subhedral, 1mm – <1 mm), and ~2% unknown mafic mineral (rectangular, ~0.7 – >1cm). The majority of carbonate grains are white to grey, a small portion are light pink, and all range from ~1mm to ~1cm. No metamorphic minerals or metamorphic textures (i.e. foliation) are present in this rock, indicating that this dyke was emplaced after greenschist metamorphism (D₂).

Carbonatites are classified as an igneous rock containing more than 50% modal carbonate minerals and less than 20 wt% SiO₂ (Le Maitre et al., 2002). In addition, carbonatites contain higher concentrations of REEs than any other igneous rock, with concentrations anywhere from 500ppm to over 1000ppm (Xu et al., 2010). This sample contains ~90% modal carbonate minerals, has 1.43 wt% SiO₂, and has very high REE concentrations (up to 476ppm of La) (Appendix F). Therefore, this sample can be considered a carbonatite and the geochemical carbonatite classification table of Le Maitre et al. (2002) can be used to apply a geochemical classification. As seen in Figure 4.5 (B), sample 628 plots in the “calciocarbonatite” field, and is classified as such.



Figure 4.4: Outcrop photo (A) and hand sample photo (B) of sample 628. The carbonatite dyke sampled is outlined in white on the right-hand side, with the general sampling location indicated with a white circle.

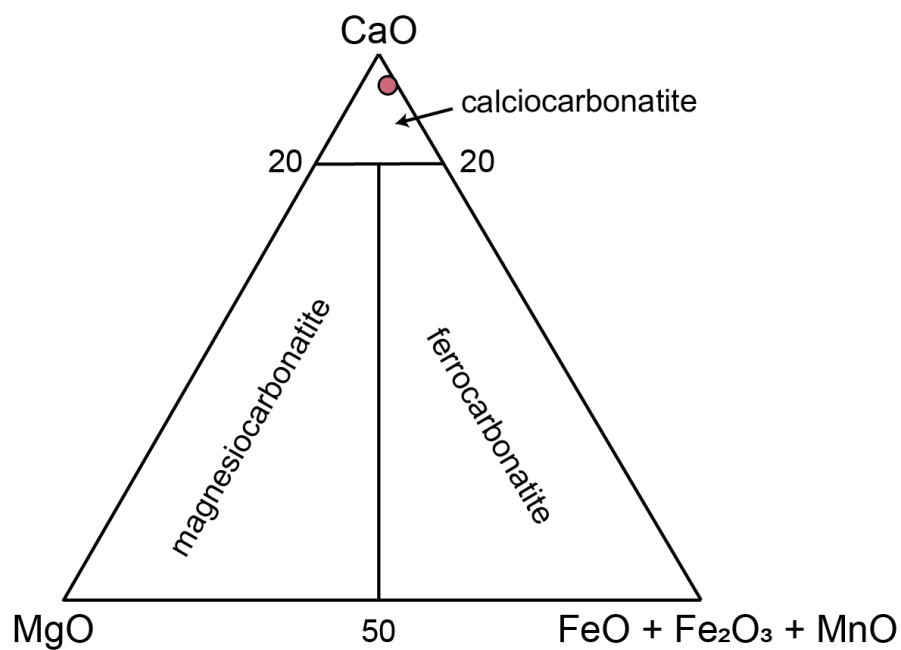


Figure 4.5: Carbonatite classification diagram modified from Le Bas and Streckeisen (1991). Sample 628 is plotted as a pink circle in the calciocarbonatite field.

4.1.1.1 Alteration Level Discrimination

Samples were categorized into four alteration categories (least altered, weakly altered, moderately altered, and strongly altered) based on whole rock K_2O and S weight percent values, following the discrimination technique of Ciufu (2019). K_2O and S increase with increasing alteration intensity from V1-V2 veining, as do Au, As, Bi, Te, Rb, Se, and Tl (Ciufu, 2019).

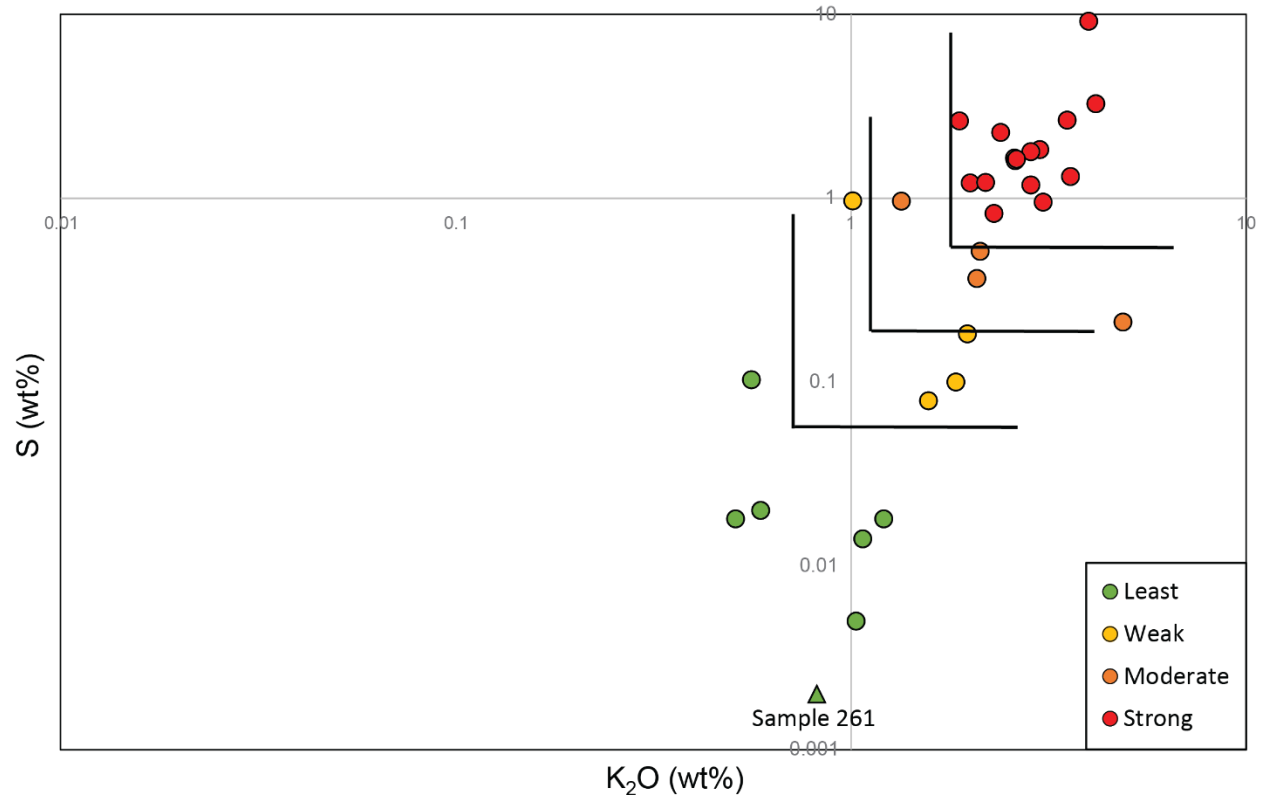


Figure 4.6: Alteration level discrimination of all samples after Ciufu (2019). Samples are divided based on their whole rock K_2O wt% and S wt% values. Higher concentrations of both K_2O and S correspond to stronger alteration. The green triangle is sample 261; see text for discussion of this sample.

The S and K_2O concentrations in sample 261 (green triangle, Figure 4.6) would classify it as a “least altered” sample, however the mineralogy and textures observed in thin section do not match with this result. In thin section, sample 261 has a quartzo-feldspathic groundmass that is strongly altered by white mica and carbonate and foliation is defined by stretched carbonate grains and bands of chlorite, which are folded (Figure 4.8, A and B). This discrepancy between petrographic observations and geochemical classification may be due to the vein types associated

with this sample; all vein types, V1-V2, V3, and V4 (Section 1.1), are present adjacent to this sampling location and it is the only sample in this study proximal to a V3 vein; consequently, it is the only sample that may be influenced by V3 alteration. The S vs K₂O sample classification of Ciufo (2019) is based on alteration due to V1-V2 veining, and so any alteration by a V3 vein may make the results of this classification scheme incorrect. Therefore, petrographic observations will be used to classify the alteration level of this sample, and results from Figure 4.6 will be disregarded. Sample 261 is considered strongly altered due to the high proportion of white mica and carbonate alteration of the quartzo-feldspathic groundmass.

Sample 622 is not included on the alteration classification scheme as it is a vein-rich sample, primarily composed of V1-V2 material and small amount of dacite wall rock. Due to this, it will be classified as “strongly altered” for simplicity.

4.1.1.2 Petrography

All samples have a quartzo-feldspathic groundmass with varying amounts of chlorite, carbonate, biotite, and white mica depending on the alteration level of each sample, and minor accessory minerals. In general, increasing alteration strength results in an increase in white mica and carbonate, and a decrease in chlorite and biotite.

Least altered samples have porphyritic texture with a quartzo-feldspathic groundmass and phenocrysts of plagioclase, quartz, and minor biotite (Figure 4.7, A). Phenocrysts are slightly altered by carbonate and muscovite. Chlorite overprints this texture and defines the foliation. Carbonate is present in trace amounts as small veinlets and/or discrete fine grains within groundmass in some samples. Minor magnetite is distributed throughout groundmass, and trace sulfides (e.g. pyrite) are found in some samples.

Weakly altered samples have porphyritic texture with a quartzo-feldspathic groundmass and phenocrysts of plagioclase, quartz, and biotite, which are altered by muscovite and carbonate (Figure 4.7, B). The foliation is weak, and when present it is defined by preferred orientation of chlorite and biotite. Minor calcite veinlets and quartz veinlets are present with associated pyrite and trace pyrrhotite. Magnetite is distributed randomly throughout groundmass, and coarser grained magnetite is associated with clusters of biotite grains. Other accessory minerals include apatite and trace tourmaline. Weakly altered samples have a higher proportion of biotite than least altered samples, and the biotite is coarser grained than in least altered samples.

Moderately altered samples do not display porphyritic textures due to the increased alteration by white mica and carbonate minerals. The quartzo-feldspathic groundmass is altered by carbonate minerals, white mica, and chlorite, however there is less chlorite compared to the least altered samples. The foliation is strong and is defined by preferred orientation of white mica and chlorite grains, and quartz veinlets strike parallel to foliation (Figure 4.7, C). Quartz-carbonate veins are also present, often at an oblique strike to foliation. Pyrite and lesser pyrrhotite are associated with both the quartz veinlets and quartz-carbonate veinlets, and trace tourmaline is associated with quartz veinlets.

Strongly altered samples have the highest amounts of white mica and quartz of all alteration levels and have lower amounts of chlorite and carbonate than the moderately altered samples. No porphyritic texture is present, and a strong foliation is defined by preferred orientation of white mica grains (Figure 4.7d). Quartz veins and veinlets and quartz-carbonate veinlets are abundant, and stringers of pyrite ($\pm$ pyrrhotite $\pm$ chalcopyrite) are present throughout and most strike parallel to foliation. Discrete grains of pyrite, pyrrhotite, and trace chalcopyrite

are associated with quartz veins and quartz-carbonate veins, and with tourmaline in samples that are associated with V4 veining.

Strongly altered samples associated with V4 veining have similar mineralogy and textures as those associated with V1-V2 veining, with the addition of higher amounts of tourmaline and the presence of tourmaline stringers and tourmaline-quartz veins/veinlets. Tourmaline is euhedral to subhedral, and tourmaline veinlets have a stronger alteration halo defined by an increase in white mica.

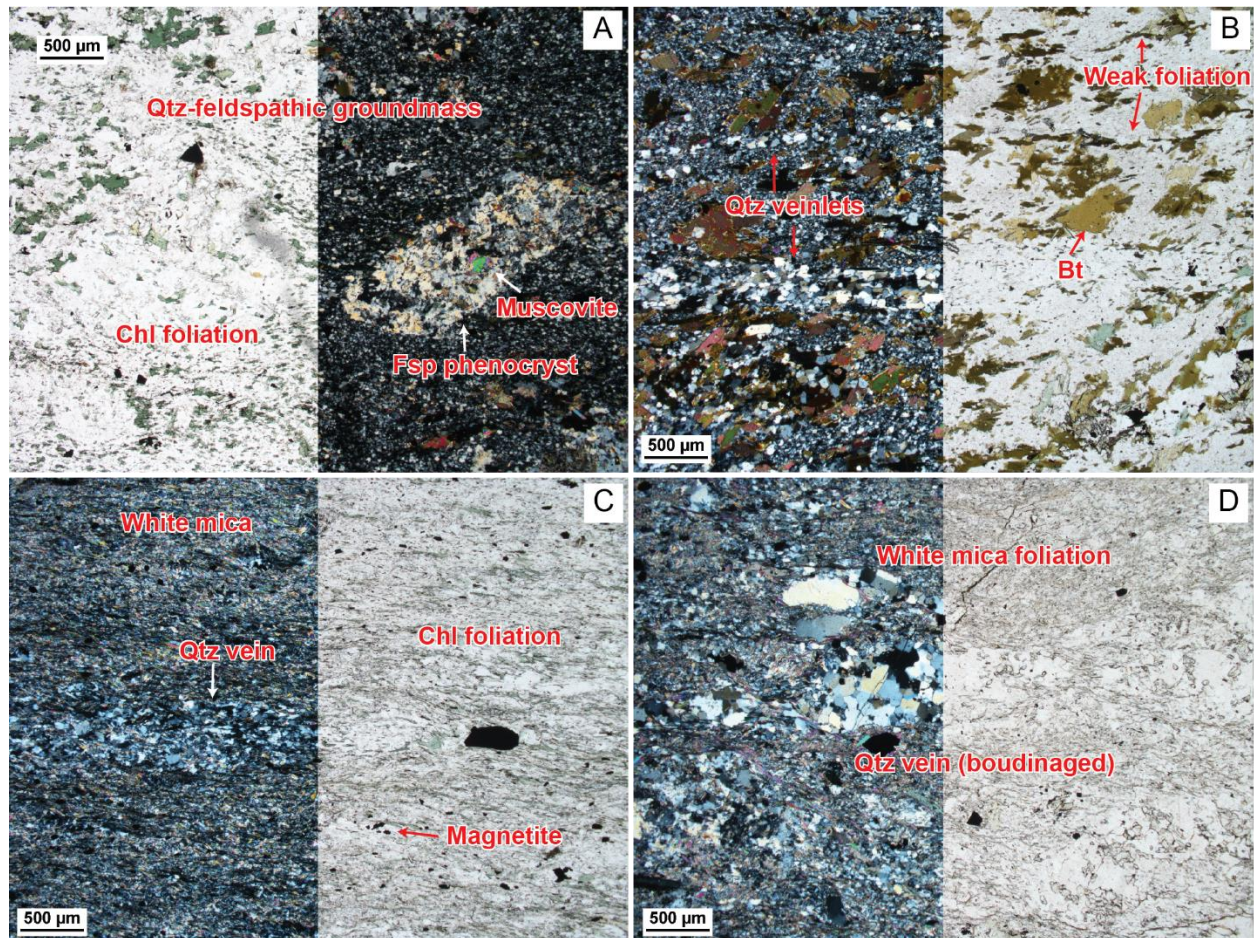


Figure 4.7: Thin sections photos of each alteration level. A: least altered (sample 605); B: weakly altered (sample 606); C: moderately altered (sample 260); and D: strongly altered (sample 620).

Sample 261 is the only sample that is proximal to a V3 vein, and the mineralogy and texture of this sample differs from the other strongly altered samples. Sample 261 has the same quartzo-feldspathic groundmass as other dacite samples, however it contains coarse-grained blebs of lenticular calcite. The centre of the calcite grains contain inclusions of a felsic mineral (possibly quartz or feldspar) that form round to rectangular shapes, suggesting that the calcite has replaced pre-existing protolith phenocrysts. Inclusion free calcite is present on either side of these inclusion-rich centres, tapering to points on each side creating the lenticular shape (Figure 4.8, A). Chlorite defines the foliation and bends around the coarse calcite blebs, producing a weak augen texture. Quartz veinlets are present and are boudinaged; calcite is present within the boudin necks of these quartz veins (Figure 4.8, B), which is the same cross-cutting relationship as the V3 veins at mine scale (Jellicoe et al., 2022).

Sample 623 is a strongly altered dacite associated with V1-V2 veining, however it differs from the other strongly altered samples as it is proximal to a diabase dyke (unit I3DD in Island Gold mine nomenclature). This sample was collected to explore the impact of the dyke emplacement on the dacite host rock and to ascertain if young ages correlate with dyke location. This sample has similar textural features and general mineralogy (quartzo-feldspathic groundmass altered by white mica and carbonate, however it contains epidote while the other strongly altered samples do not. Epidote is subhedral to anhedral, ranges from <0.2mm to ~1mm, and is primarily associated with areas of high concentrations of white mica (Figure 4.8, C).

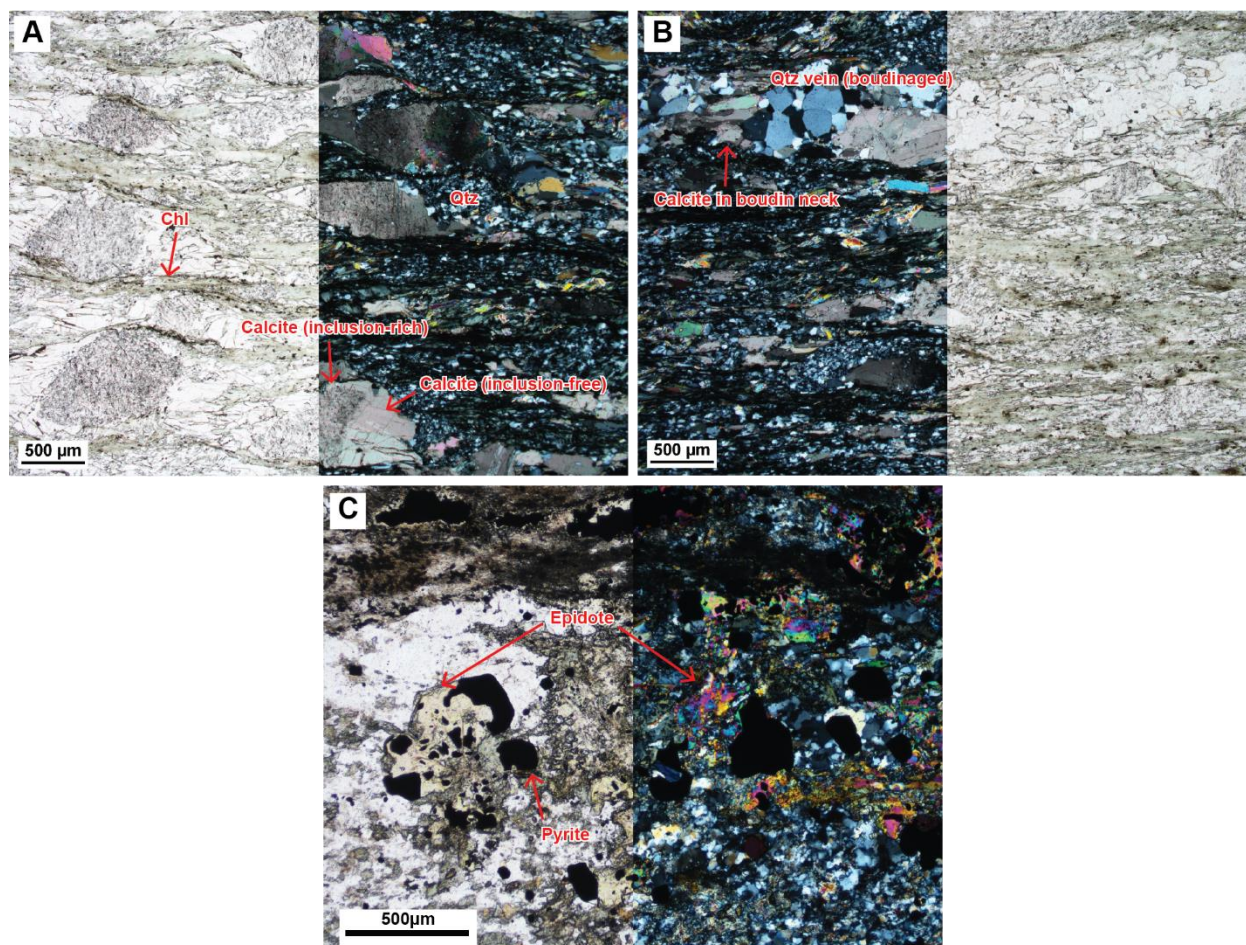


Figure 4.8: Thin section pictures of sample 261 (A and B) and 623 (C). A: displays inclusion-rich and inclusion-free lenticular calcite grains with weak augen texture. B: Boudinaged quartz vein with boudin necks filled with calcite. C: Epidote within an altered area of a quartzo-feldspathic groundmass.

4.2 Geochronology

4.2.1 Summary

Thirty-three samples were processed for zircon separation, however not all samples contained enough zircon to allow for statistically acceptable geochronological analysis. For this thesis, a minimum of ten zircon grains is considered acceptable for consideration. Nineteen of the thirty-three samples contained ten or more zircon grains and are included here. Sample characteristics and $^{207}\text{Pb}/^{206}\text{Pb}$ date ranges and average ages are summarized in Table 1. Geochronologic data from the remaining nine samples with less than ten zircon grains are included in Appendix B, and no zircons were retrieved from five samples.

A number of zircons were picked for each sample, however not all grains were analyzed. Grains with characteristics of the previously discovered Proterozoic ages (dark rims and/or indistinct internal zonation) (Ciufo, 2019) were targeted for analysis, and therefore a small population of grains that were mounted and imaged were analyzed for U-Pb isotopes. Representative selections of CL images for each sample are included with geochronological data. Some CL images contain apatite grains which appear as bright white, streaked grains, and can be disregarded.

Most samples give date ranges and average ages comparable to the previously calculated crystallization age of the dacite host at Island Gold, 2735 ± 8 Ma (Ciufo, 2019). A summary of these results is discussed in Section 0, and detailed results for each sample can be found in Appendix B. Six samples (622, 260, 261, 263, 264, and 266) display two discrete Archean-aged zircon populations. For each sample, these two populations are subdivided into groups in Table 4.2 and in their respective concordia and weighted mean diagrams (Section 4.2.3). The division between groups was determined first by examining the clustering of data points on a Tera-Wasserburg concordia diagram and a $^{207}\text{Pb}/^{206}\text{Pb}$ date distribution diagram, then refined using the $^{207}\text{Pb}/^{206}\text{Pb}$ dates for each sample. Of these samples, samples 622 and 260 contain one subgroup with dates that correspond to the inferred protolith age (~ 2735 Ma) and one subgroup with a younger Archean age (~ 2632 Ma in sample 622 and ~ 2697 Ma in sample 260) and the remaining samples produced two younger Archean date groups (Section 4.2.3.2). Sample 262 produced a single $^{207}\text{Pb}/^{206}\text{Pb}$ average population of ~ 2642 Ma ($\sim 2620 - 2660$ Ma date range).

Table 4.2: Summary of samples analysed for geochronology. Sample name, alteration level, number of zircons analysed, and $^{207}\text{Pb}/^{206}\text{Pb}$ age are included.

Sample Number	Alteration level	Number of zircons	Average $^{207}\text{Pb}/^{206}\text{Pb}$ date (Ma)	Date Range (Ma)
602	Weak	29/32	~2732	~2758 – 2654
607	Least	14/15	~2754	~2774 – 2737
608	Weak	31/31	~2754	~2779 – 2715
611	Strong	27/31	~2725	~2764 – 2686
612	Weak	48/50	~2737	~2766 – 2699
613	Moderate	90/95	~2741	~2771 – 2711
614	Strong	27/31	~2724	~2747 – 2713
615	Least	78/83	~2743	~2768 – 2695
616	Least	47/51	~2735	~2771 – 2704
620	Strong	53/56	~2728	~2775 – 2704
621 (protolith age)*	Strong	53/55	~2739	~2770 – 2700
622 (Group 1)	Strong	59/59	~2740	~2772 – 2697
622 (Group 2)	Strong	29/29	~2633	~2682 – 2594
628 (Group 1)**	Carbonatite	4/4	~1403	~1419 – 1362
628 (Group 2)	Carbonatite	11/11	~2646	~2663 – 2628
260 (Group 1)	Moderate	44/44	~2739	~2758 – 2723
260 (Group 2)	Moderate	48/50	~2697	~2718 – 2673
261 (Group 1)**	Least	9/11	~2671	~2673 – 2648
261 (Group 2)	Least	27/27	~2712	~2719 – 2674
262	Strong	33/33	~2642	~2667 – 2620
263 (Group 1)**	Strong	7/7	~2642	~2645 – 2628
263 (Group 2)	Strong	27/27	~2675	~2703 – 2663
264 (Group 1)	Strong	18/18	~2670	~2683 – 2663
264 (Group 2)	Strong	11/11	~2697	~2706 – 2693
266 (Group 1)	Moderate	14/15	~2653	~2671 – 2625
266 (Group 2)	Moderate	9/9	~2712	~2725 – 2692

*A subset of zircon grains from sample 621 give Proterozoic ages and are discussed in detail in section 4.2.4.2.

**Less than 10 zircon grains are included in this group. This group is included because it is a subset of a larger set of analyses from a single sample.

All retained data points from all samples are plotted on a kernel density estimate (KDE) plot (Figure 4.9). This KDE plot shows that there are three peaks, corresponding to three clusters of ages: one at ~2620-2650 Ma (youngest peak), one at ~2660-2690 Ma (mid-peak) and one around the protolith age of ~2730-2750 Ma (protolith peak).

The youngest peak consists of 51 analyses found across 4 samples: 622, 262, 263, and 266. The majority of the youngest peak analyses are from sample 262 and 622. The mid-peak consists of 73 analyses across 7 samples: 622, 260, 261, 262, 263, 264, and 266, and the majority of the mid-peak analyses are from samples 263 and 264. Both the youngest peak and the mid-peak are moderately discrete from their adjacent histogram bins of dates (Figure 4.9). The protolith-peak consists of 306 analyses from an array of samples, each of which is discussed individually in detail in Section 0. There is a large number of analyses between the dates of ~2700-2730 Ma, creating a lagging tail adjacent to the protolith-aged peak. Some of these dates are likely due to wide range of individual dates of the protolith-aged samples (see Section 0), however there are several samples that give groups of age ranges and average $^{207}\text{Pb}/^{206}\text{Pb}$ dates at ~2700 Ma (260 Group 2, 261 Group 2, 264 Group 2, 266 Group 2) (see Section 4.2.3).

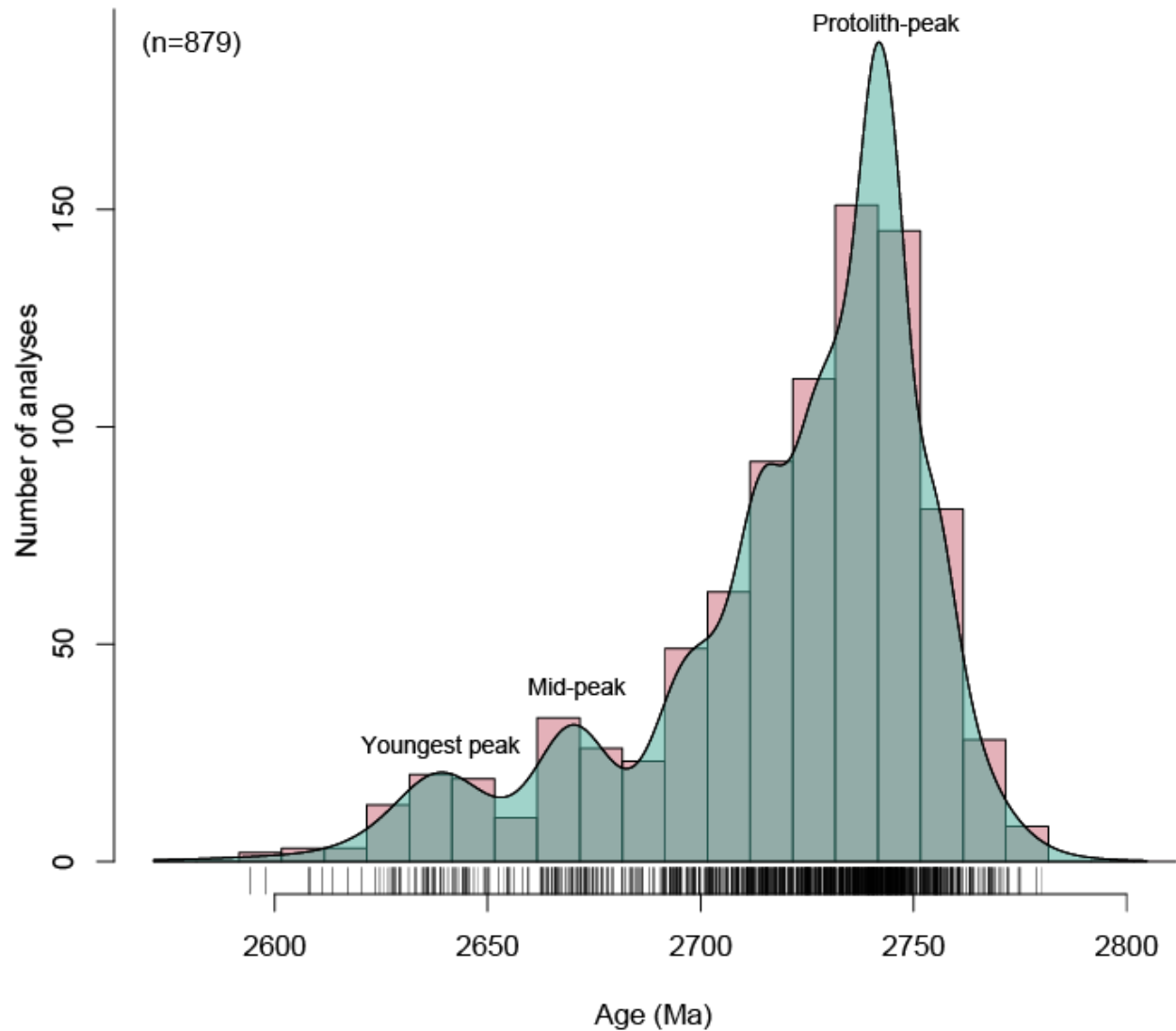


Figure 4.9: Kernel density estimate plot of all zircon grains analyzed from all samples. Analyses omitted from weighted mean age calculations and concordia diagrams of individual samples were not included in this diagram, resulting in a total of 879 points. Histogram bins are 10 Ma in width. Three peaks are visible, the first at ~2620-2650 Ma (youngest peak), the second at ~2660-2690 Ma (mid-peak), and the third at ~2730-2750 Ma (protolith peak).

4.2.2 Protolith-aged Samples

Zircon U–Pb analyses from 13 of the 19 samples give $^{207}\text{Pb}/^{206}\text{Pb}$ date ranges and average dates comparable to the previously reported crystallization age of the protolith at 2735 ± 8 Ma (Jellicoe et al., 2022). Samples range from least altered to strongly altered, are primarily drill core samples and all are associated with V₁–V₂ veining. Average ages range from ~2724 Ma to ~2754 Ma, with a complete date range of ~2686 – 2775 Ma and are summarized in Table 4.3.

Table 4.3: Protolith-aged samples, ordered according to alteration level, detailing $^{207}\text{Pb}/^{206}\text{Pb}$ average dates and date ranges.

Sample Number	Alteration level	N zircons	Average $^{207}\text{Pb}/^{206}\text{Pb}$ dates (Ma)	Date range (Ma)
602	Weak	29/32	~2732	~2691 - 2757
607	Least	14/15	~2754	~2736 - 2768
608	Weak	31/31	~2754	~2715 - 2778
611	Strong	27/31	~2725	~2686 – 2763
612	Weak	48/50	~2737	~2698 – 2766
613	Moderate	90/95	~2741	~2708 - 2749
614	Strong	27/31	~2724	~2712 – 2747
615	Least	78/83	~2743	~2695 – 2768
616	Least	47/51	~2735	~2704 - 2755
620	Strong	53/56	~2728	~2704 - 2775

Each sample is described in this section, including a summary of the morphology of zircon grains analyzed, cathodoluminescence (CL) images of internal zoning patterns, concordia and date distribution diagrams, and the average $^{207}\text{Pb}/^{206}\text{Pb}$ date and date range. The geological significance of these averages is unclear due to the spread in the individual sample date ranges, but they are interpreted as poorly constrained ages of crystallization of the protolith.

Sample 602: weakly altered dacite, drill core sample, associated with V₁–V₂ veining.

Seventy-eight zircons were picked and 33 were analyzed. The zircons are ~40 μm in size, subhedral to anhedral, and display sector and oscillatory zoning as well as indistinct zoning (Figure 4.10). Across all zoning patterns, 29/33 grains give a date range from ~2691 to 2757 Ma,

which yield a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2732 Ma (Figure 4.14). Sample 602 also produced one zircon grain with a $^{206}\text{Pb}/^{238}\text{U}$ date of ~ 542 Ma; this grain will be discussed in Section 4.2.4.2.

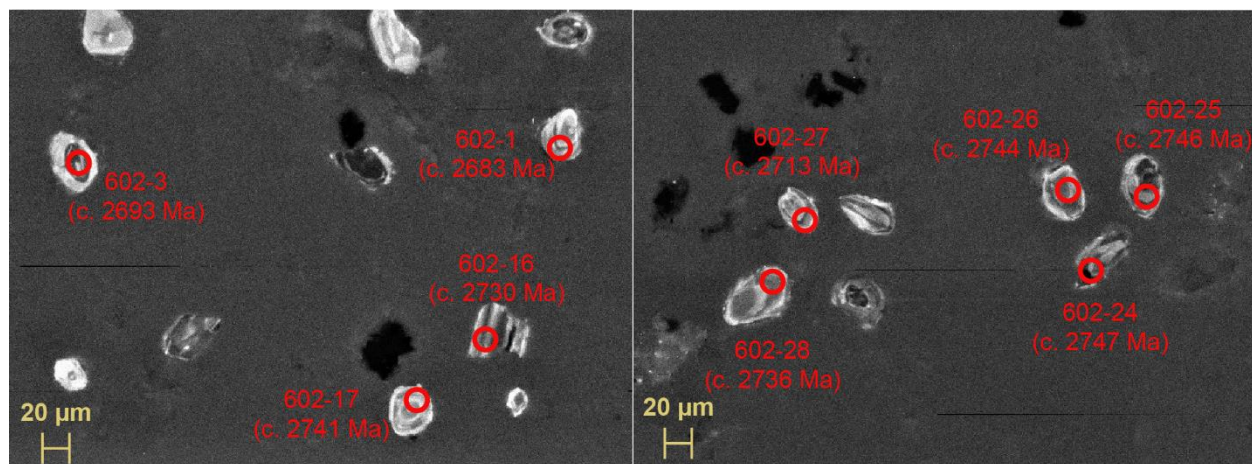


Figure 4.10: CL images of 9 zircon grains analysed from sample 602. These images are representative of the typical internal zonation seen in this sample. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 607: least altered dacite, drill core sample, associated with V1-V2 veining.

Twenty-five zircon grains were picked, mounted, and polished, and 15 were analyzed from sample 607. The grains ranged from ~ 30 - 50 μm and are subhedral. Grains displayed distinct sector and oscillatory zoning (Figure 4.11). 14 of the 15 grains give a date range of ~ 2736 to 2768 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2754 Ma. Some grains display weak discordance on a Tera-Wasserburg concordia diagram (Figure 4.14).

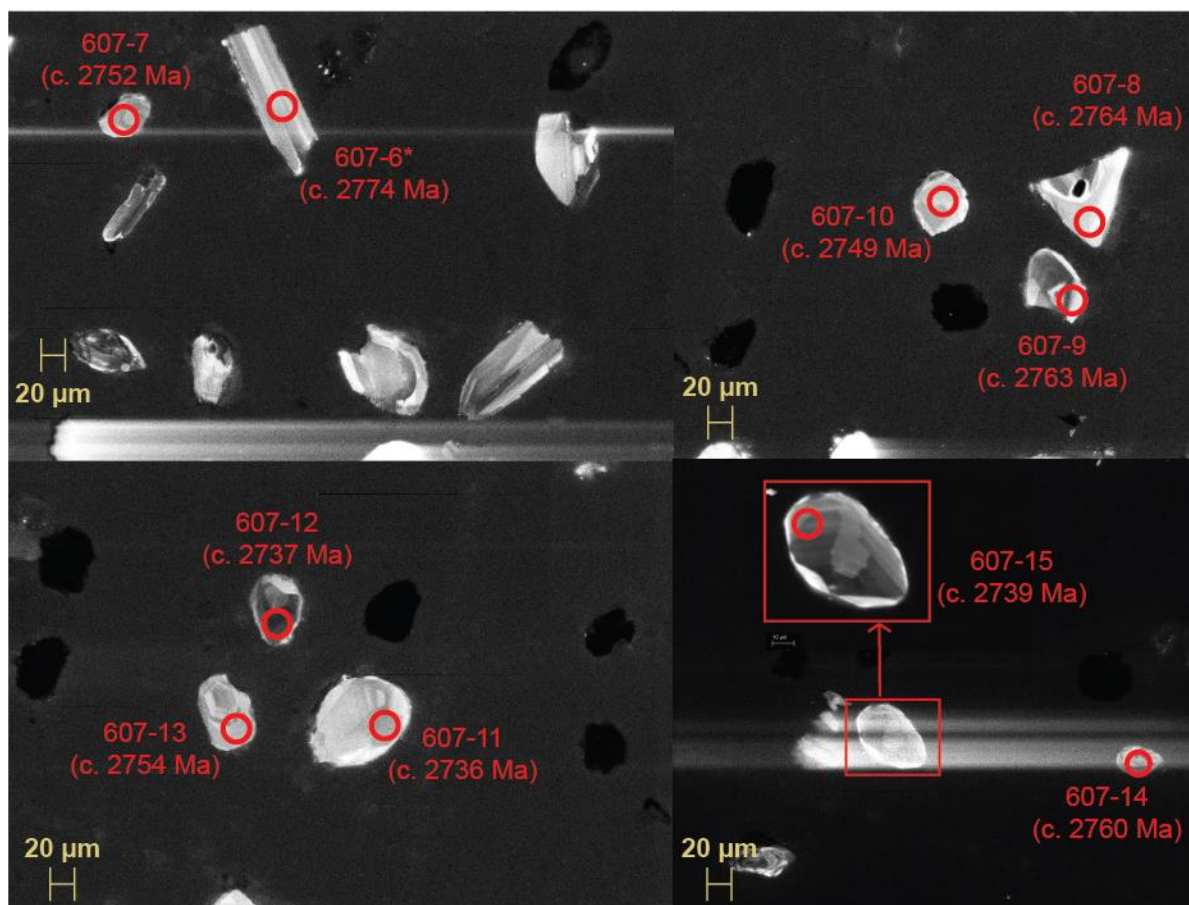


Figure 4.11: CL images of 10 representative zircon grains analysed from sample 607. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point. Spots with an asterisk indicate this analysis point was omitted from weighted mean age calculations.

Sample 608: weakly altered dacite, drill core, associated with V1-V2 veining.

Fifty zircon grains were picked, mounted, and polished, and 31 were analyzed. Most grains were $\sim 40\mu\text{m}$ with a small number closer to $\sim 60\mu\text{m}$. Most were subhedral to anhedral with equant proportions and rounded edges. Grains displayed distinct sector and oscillatory zoning (Figure 4.12). All 31 grains give a date range of ~ 2715 to 2778 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2754 Ma. Some grains display weak reverse discordance on a Tera-Wasserburg concordia diagram (Figure 4.14).

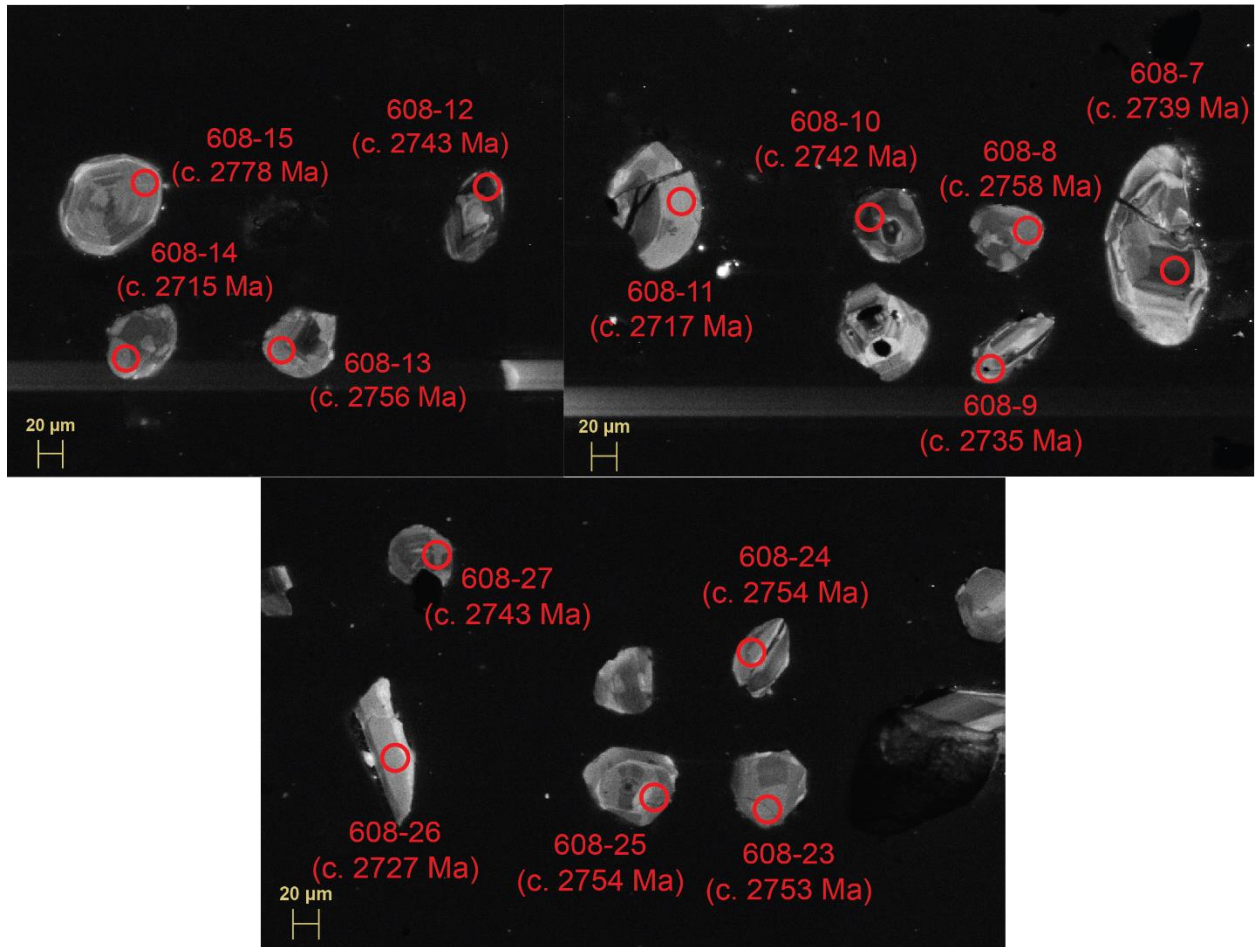


Figure 4.12: CL images of 13 representative zircon grains analysed from sample 608. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 611: strongly altered dacite, drill core sample, associated with V1-V2 veining.

Two-hundred-and-one zircon grains were picked, mounted, and polished, and 31 were analyzed. Oval grains were $\sim 25\text{-}40\mu\text{m}$ while the elongate oval grains could be up to $60\mu\text{m}$ in length. Grains displayed distinct sector and oscillatory zoning (Figure 4.13). 27/31 grains give a date range of ~ 2786 to 2763 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2725 Ma. Some grains display weak reverse discordance on a Tera-Wasserburg concordia diagram, and some display weak normal discordance (Figure 4.14).

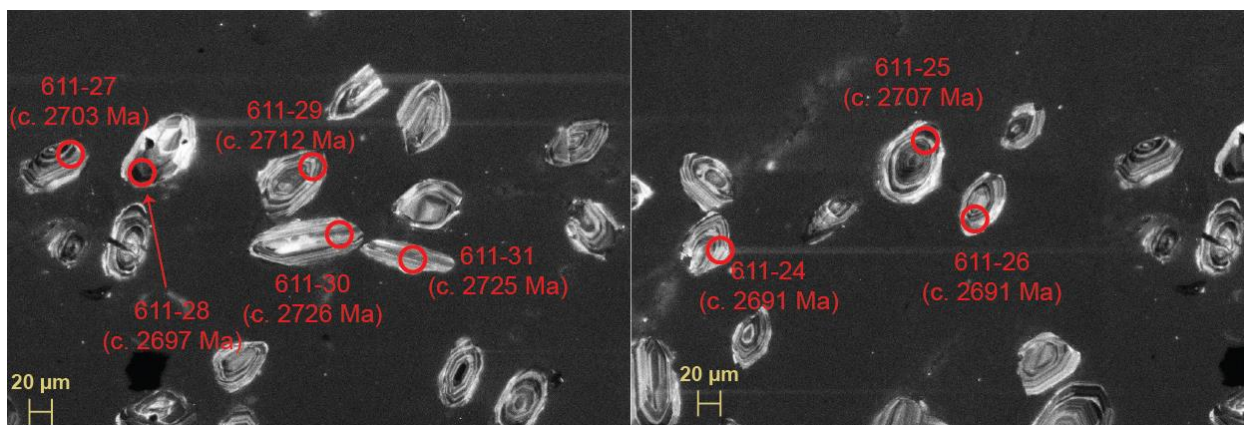


Figure 4.13: CL images of 8 representative zircon grains analysed from sample 611. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

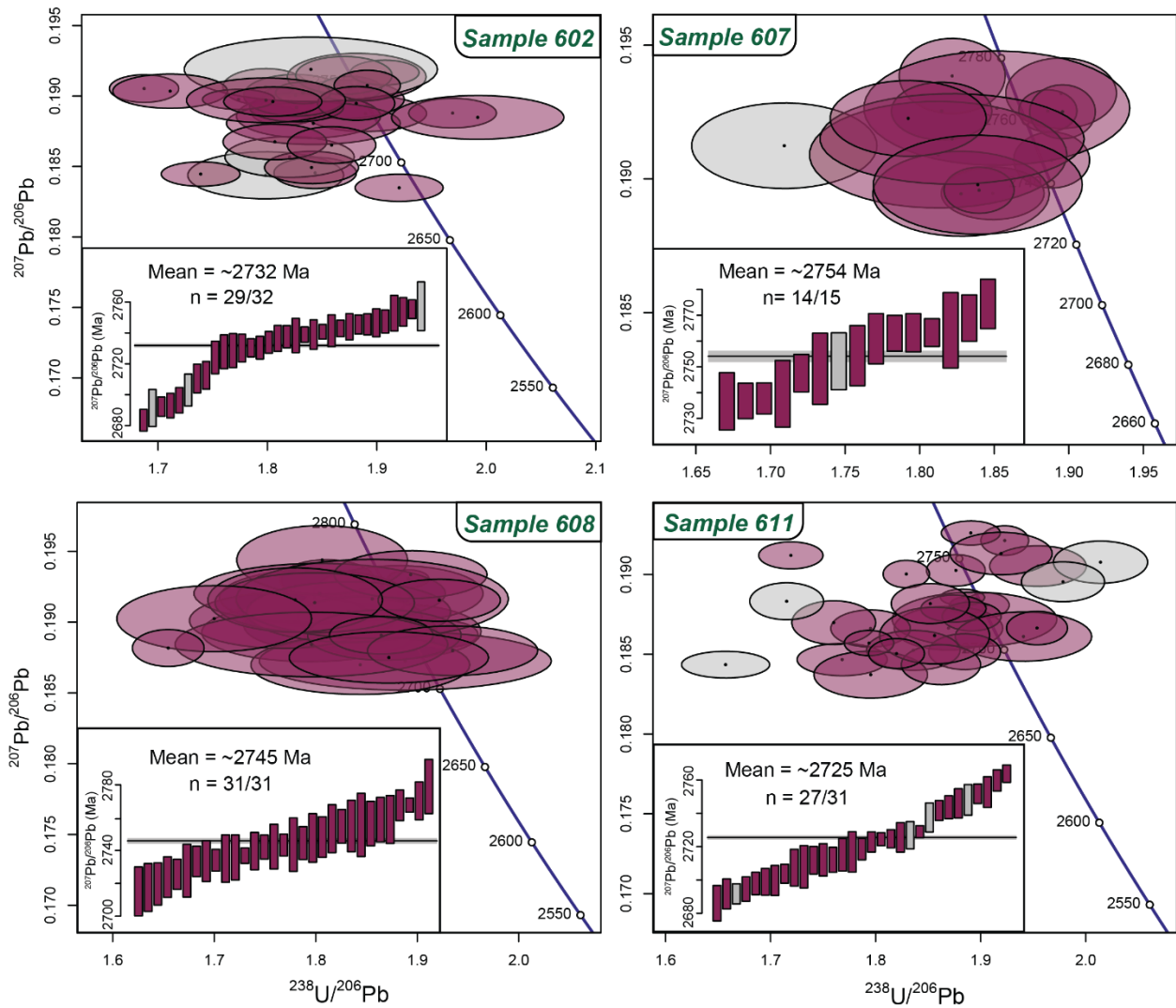


Figure 4.14: Concordia and weighted mean diagrams of samples 602, 607, 608, and 611. Approx. $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean ages and the number of grains included in the calculation for each sample are listed. Ellipses and bars in red are analyses included in the weighted mean age calculation, and those in grey were omitted.

Sample 612: weakly altered dacite, drill core sample, associated with V1-V2 veining.

Two-hundred-and-seventy-two zircon grains were picked, mounted, and polished, and 50 were analyzed. In general, grains were subhedral and oval shaped, and some displayed pointed ends. Grains ranged from ~25-60 μm , with the majority being ~40 μm . Grains displayed distinct sector and oscillatory zoning (Figure 4.15). 48/50 grains give a date range of ~2698 to 2766 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2737 Ma. Most grains display weak reverse discordance on a Tera-Wasserburg concordia diagram (Figure 4.19).

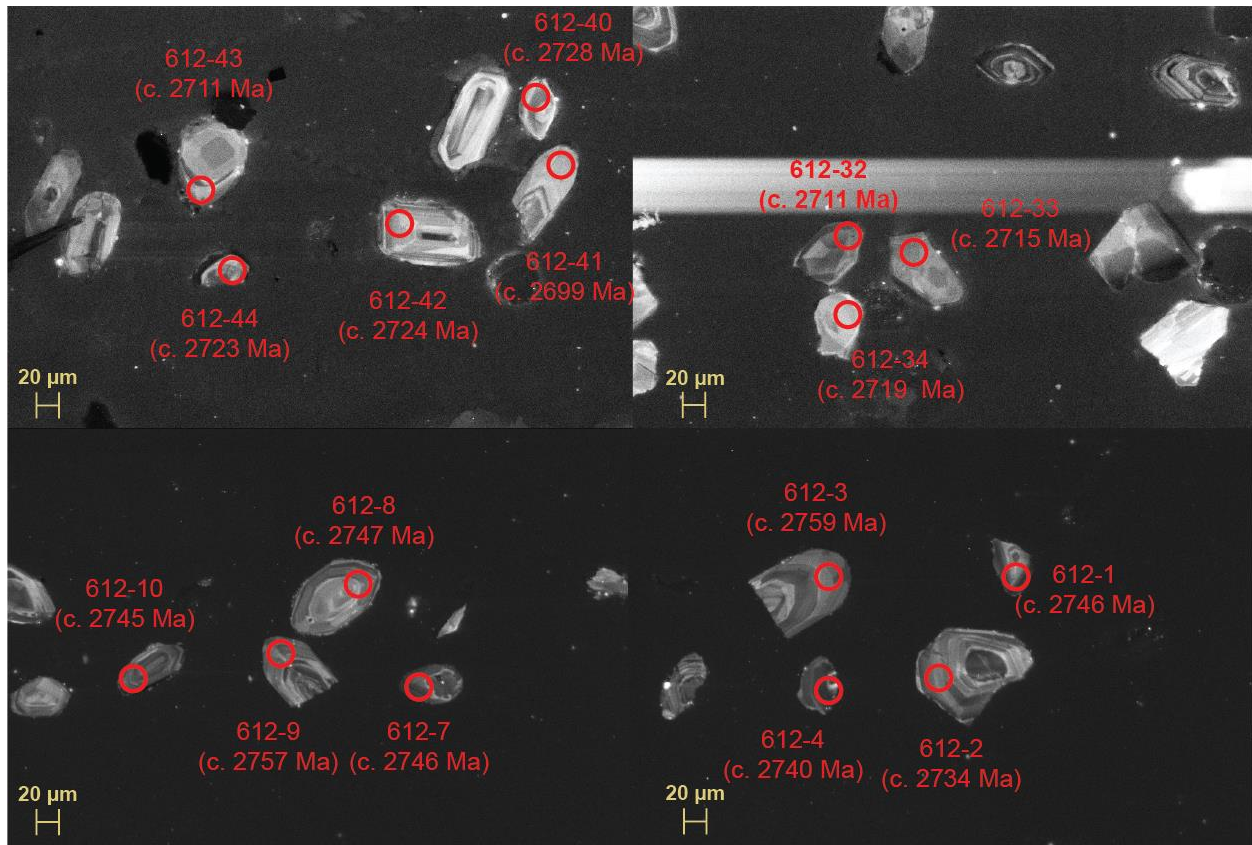


Figure 4.15: CL images of 16 representative zircon grains analysed from sample 612. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 613: moderately altered dacite, drill core sample, associated with V1-V2 veining.

Three-hundred-and-sixty zircon grains were picked, mounted, and polished, and 95 were analyzed. The majority of grains were subhedral and oval to elongate oval shaped, and some displayed pointed ends. Grains ranged from $\sim 25\text{-}60\mu\text{m}$, with the majority being $\sim 40\mu\text{m}$. Grains displayed distinct sector and oscillatory zoning (Figure 4.16). 90/95 grains give a date range of ~ 2708 to 2749 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2740 Ma. Most grains display weak reverse discordance on a Tera-Wasserburg concordia diagram (Figure 4.19) and a small number show normal discordance.

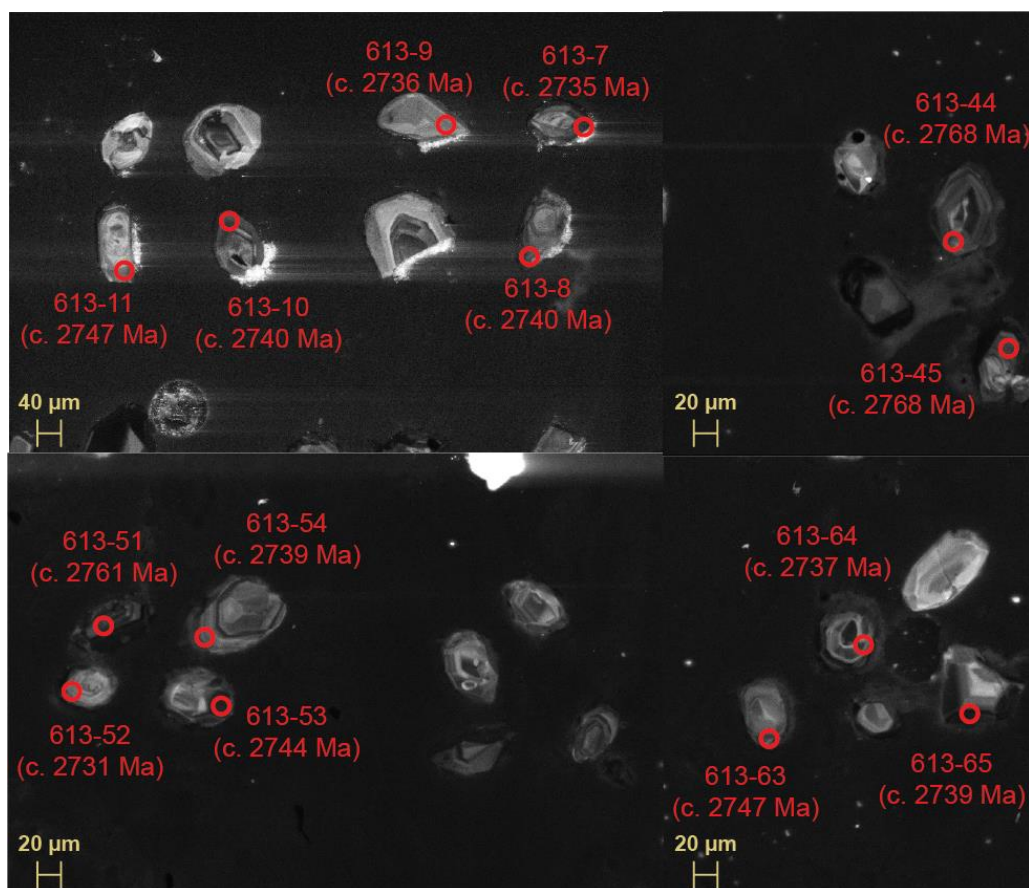


Figure 4.16: CL images of 14 representative zircon grains analysed from sample 613. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 614: strongly altered dacite, drill core sample, associated with V1-V2 veining.

One-hundred-and-six zircon grains were picked, mounted, and polished, and 31 were analyzed. Grains were subhedral and oval to elongate oval shaped, and some displayed pointed ends. Grains ranged from ~ 25 - $60\mu\text{m}$, with the majority being $\sim 40\mu\text{m}$. Grains displayed distinct sector and oscillatory zoning (Figure 4.17). 27/31 grains give a date range of ~ 2712 to 2747 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2724 Ma. Most grains display weak reverse discordance on a Tera-Wasserburg concordia diagram (Figure 4.19).

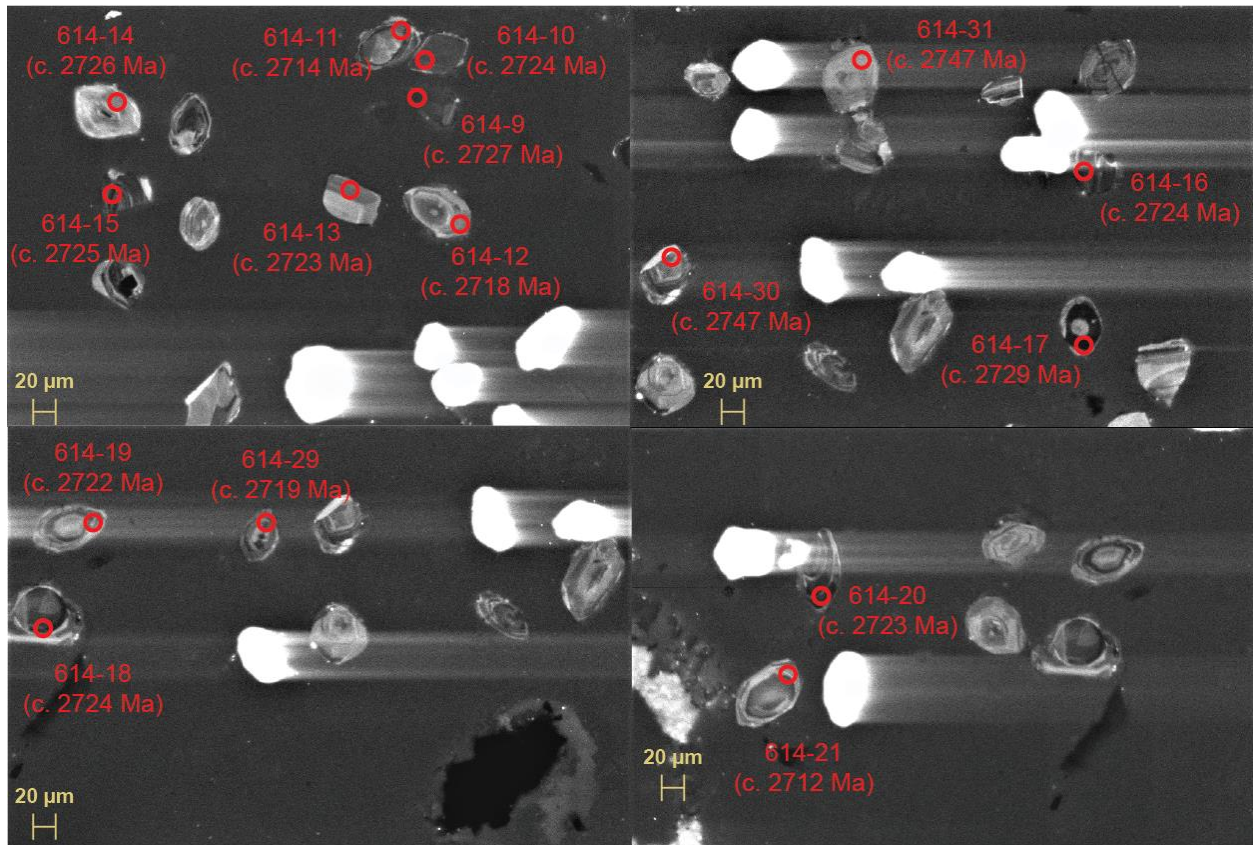


Figure 4.17: CL images of 15 representative zircon grains analysed from sample 614. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 615: least altered dacite, drill core sample, associated with V1-V2 veining.

Two-hundred-and-sixty-nine zircon grains were picked, mounted, and polished, and 83 were analyzed. The majority of grains were subhedral and oval to elongate-oval, and some displayed pointed ends. Grains ranged from $\sim 30\text{-}70\mu\text{m}$, with the majority being $\sim 40\mu\text{m}$. Grains displayed distinct sector and oscillatory zoning (Figure 4.18). 78/83 grains give a date range of ~ 2695 to 2768 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2742 Ma. The analyses cluster around concordia on a Tera-Wasserburg diagram, with some grains displaying concordance, discordance, and weak reverse discordance (Figure 4.19).

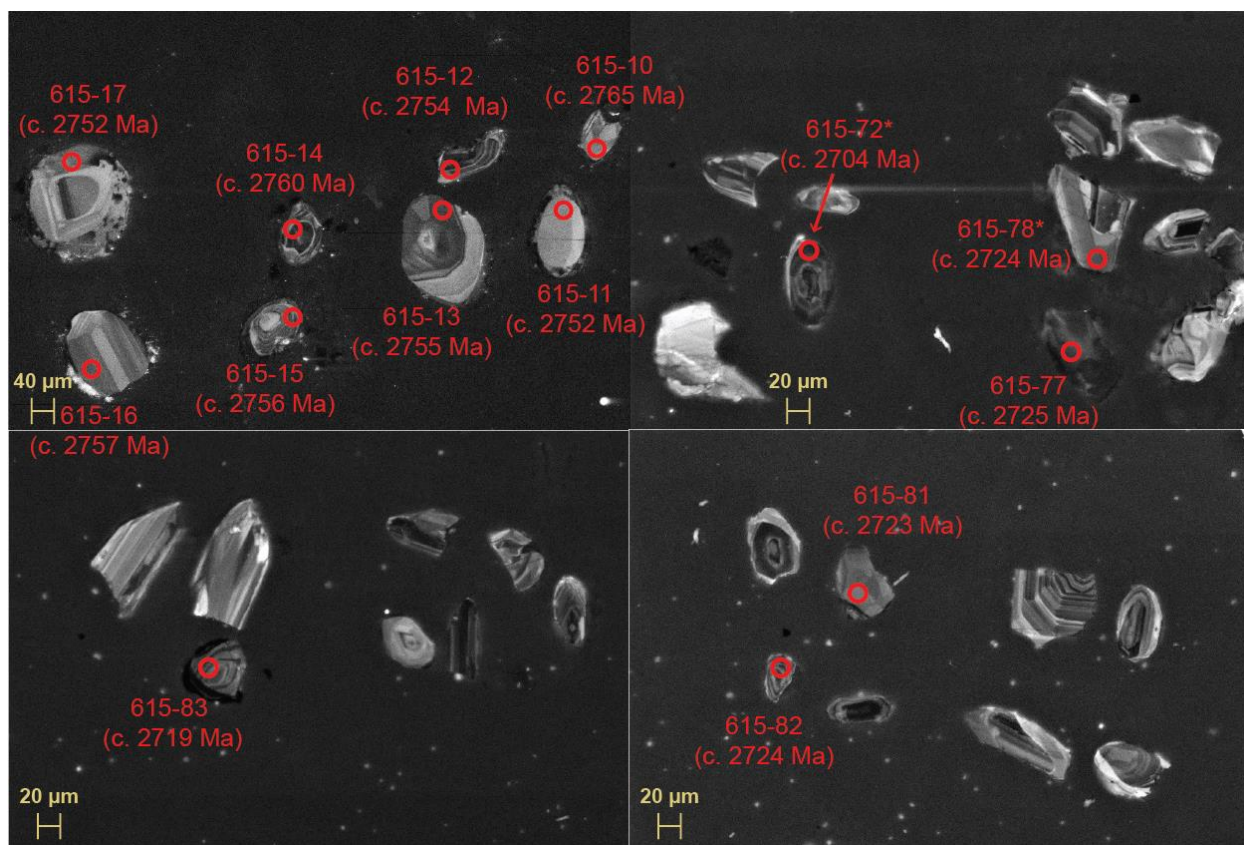


Figure 4.18: CL images of 14 representative zircon grains analysed from sample 615. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point. Spots with an asterisk indicate this analysis point was omitted from weighted mean age calculations.

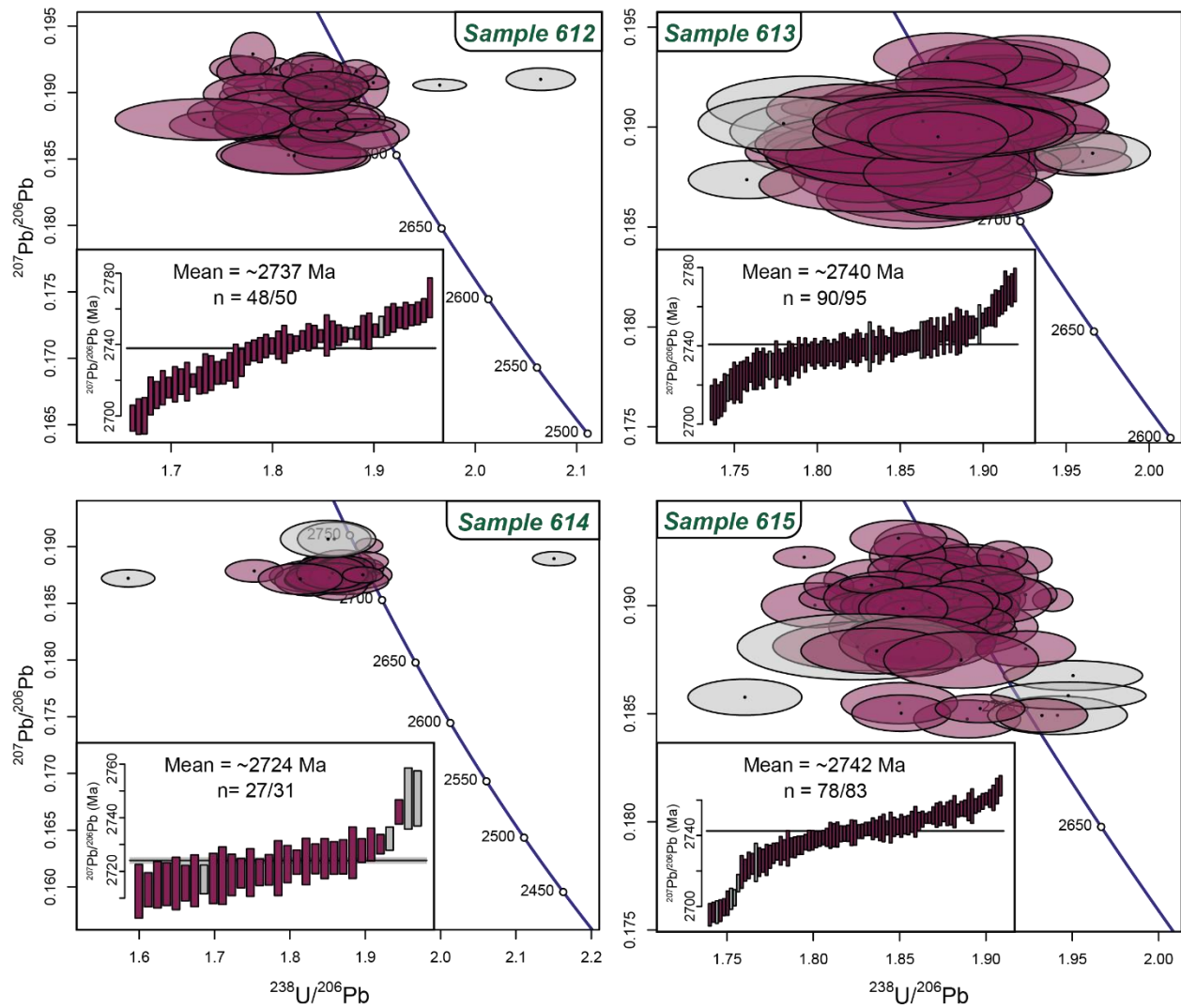


Figure 4.19: Concordia and weighted mean diagrams of samples 612, 613, 6014, and 615. Approx. $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean ages and the number of grains included in the calculation for each sample are listed. Ellipses and bars in red are analyses included in the weighted mean age calculation, and those in grey were omitted.

Sample 616: least altered dacite, drill core sample, associated with V1-V2 veining.

Three-hundred-and-three zircon grains were picked, mounted, and polished, and 51 were analyzed. The majority of grains were subhedral and oval with some displaying pointed ends. Grains ranged from ~30-50 μm , with the majority being ~40 μm . Grains displayed distinct sector and oscillatory zoning, and many had distinct cores and rims (Figure 4.20). 47/51 grains give a date range of ~2704 to 2755 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2734 Ma. Analyses

cluster around concordia on a Tera-Wasserburg concordia diagram (Figure 4.22); a few analyses show normal discordance, some are concordant, and some show reverse discordance.

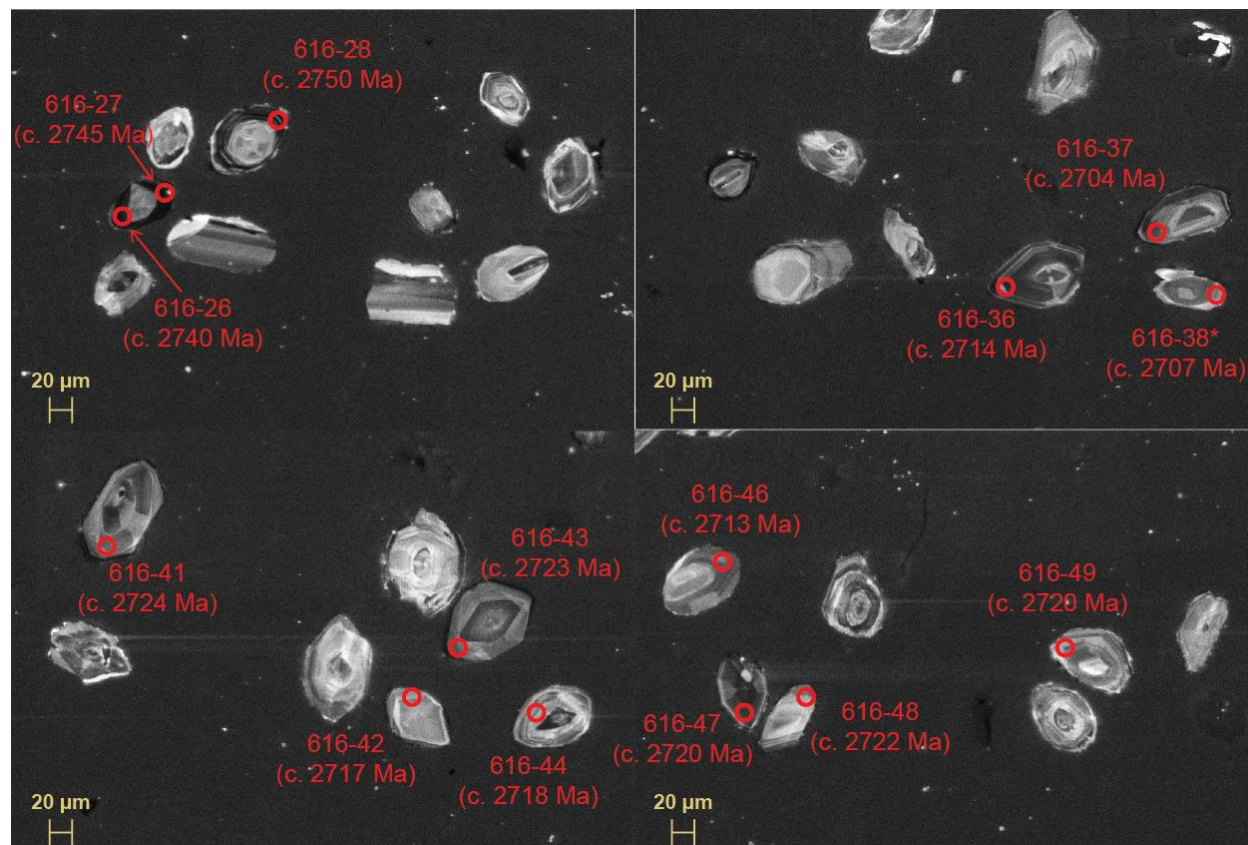


Figure 4.20: CL images of 14 representative zircon grains analysed from sample 616. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 620: strongly altered dacite, underground grab sample, associated with V1-V2 veining (East Domain, Extension 1).

71 zircon grains were picked, mounted, and polished, and 56 were analyzed. Most grains were subhedral and oval to elongate ovals, and some displayed euhedral pointed ends. Grains ranged from $\sim 30\text{-}70\mu\text{m}$, with the majority being between $35\text{-}40\mu\text{m}$. Grains displayed distinct sector and oscillatory zoning (Figure 4.21). 53/56 grains give a date range of ~ 2704 to 2775 Ma with a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2728 Ma. Most grains display weak to moderate

discordance on a Tera-Wasserburg concordia diagram (Figure 4.22), some are concordant, and a small number show reverse discordance.

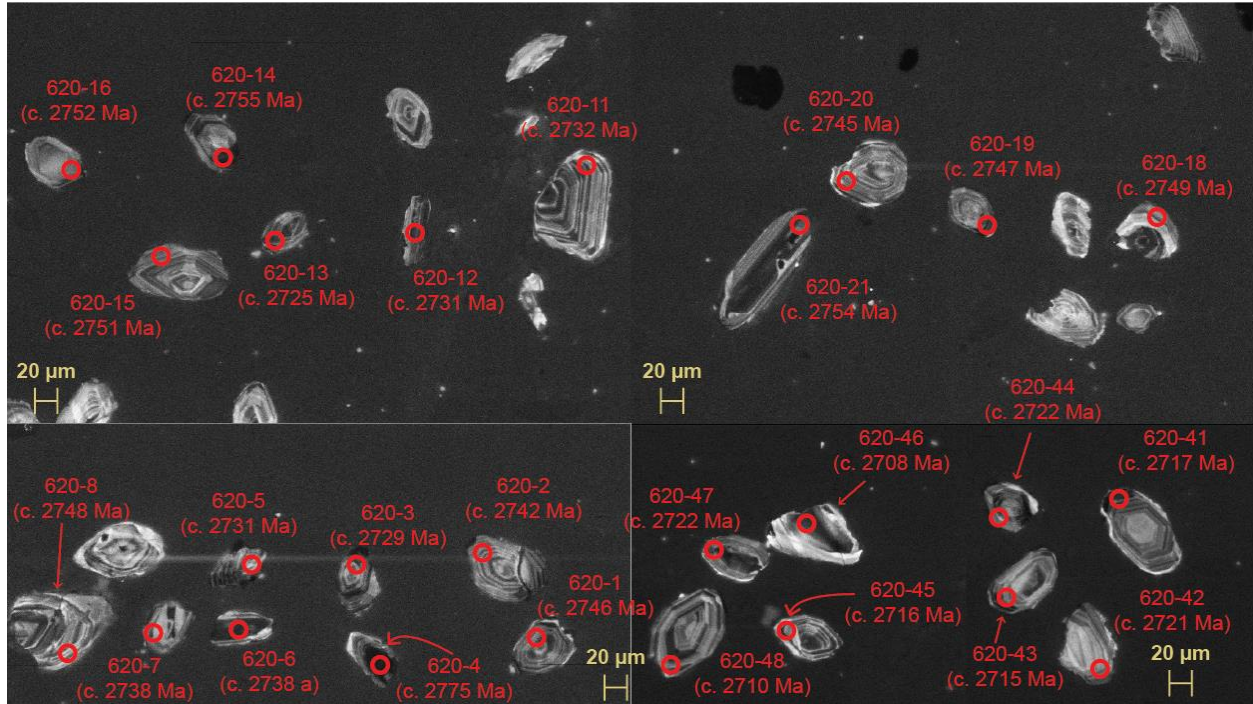


Figure 4.21: CL images of 26 representative zircon grains analysed from sample 620. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

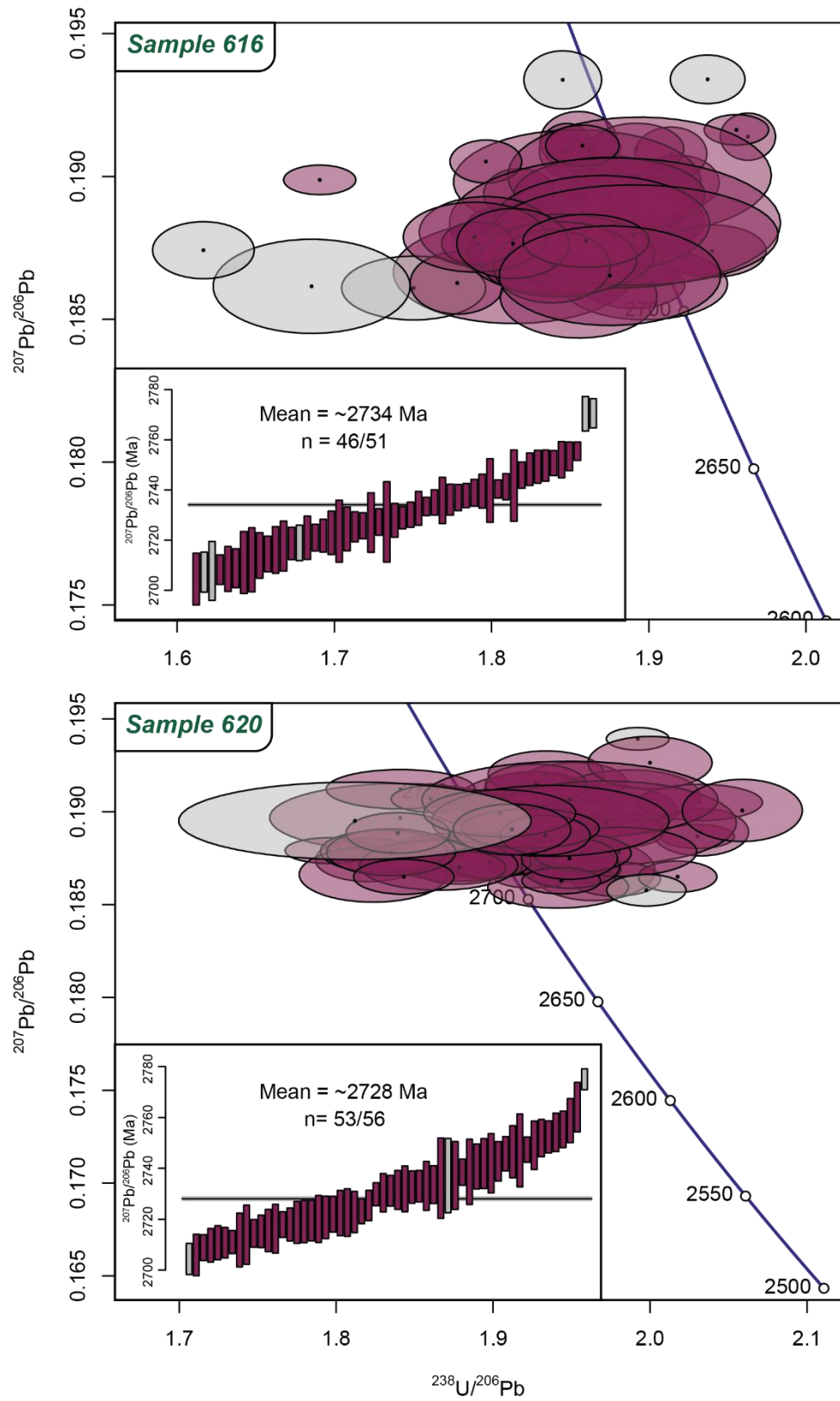


Figure 4.22: Concordia and weighted mean diagrams of samples 616 and 620. Approx. $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean ages and the number of grains included in the calculation for each sample are listed. Ellipses and bars in red are analyses included in the weighted mean age calculation, and those in grey were omitted.

All analyses from the protolith-aged populations have been compiled into one $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age diagram (Figure 4.23). These analyses give an average $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean date of ~ 2737 Ma, which is interpreted as the approximate age of the protolith rock. Previous studies presented a protolith age for the dacite host rock of Island Gold, based on zircons analysed from a least-altered sample, of 2735 ± 8 Ma (Jellicoe et al., 2022). Therefore, the approximate age calculated in this thesis is within error of the previously published age.

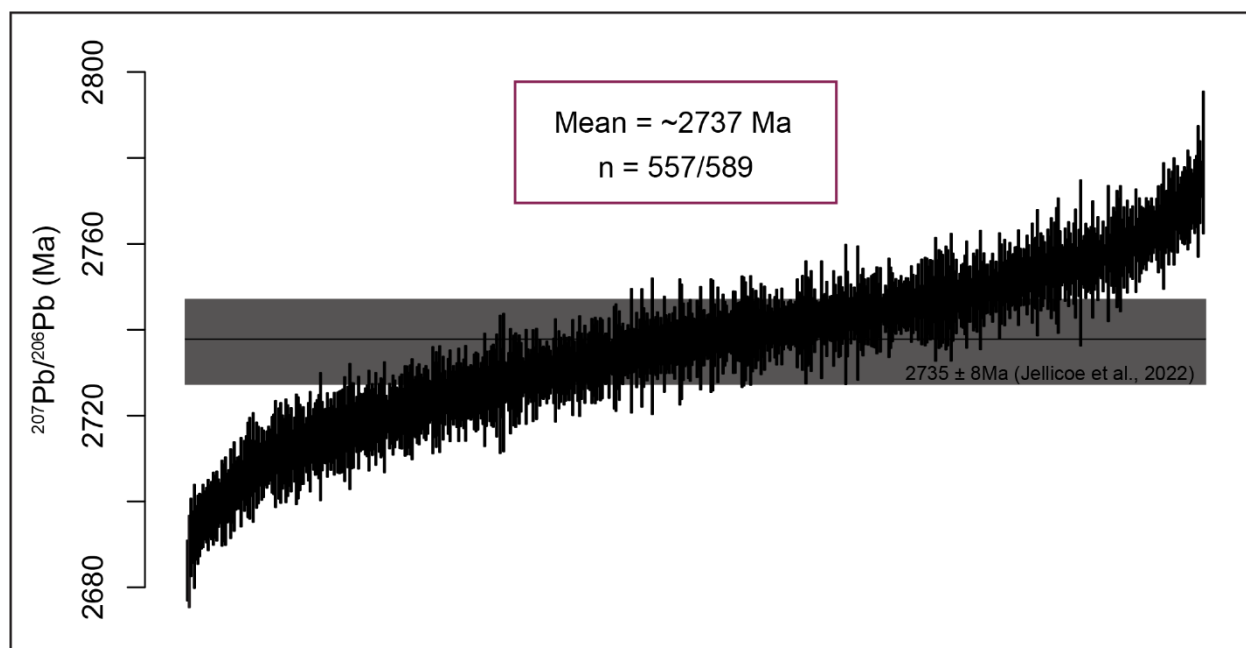


Figure 4.23: Compilation of all dates from the protolith-aged populations. The $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age is given, and the number of analyses. 32 analyses were omitted due to problems detected during ablation and raw data reduction (spikes in isotope signals indicating inclusions, drill-throughs of ablation spots, etc.). See Section 3.3.1 for more details on omission criteria. Grey box represents the protolith age determined by Jellicoe et al., (2022) – 2735 ± 8 Ma.

4.2.3 Archean ages: two subsets

Seven samples produced two sets of $^{207}\text{Pb}/^{207}\text{Pb}$ weighted mean ages; two samples produced an inferred protolith-aged group and a younger Archean-aged group, and five samples produced two groups of younger Archean ages. These samples will be discussed individually below.

4.2.3.1 Protolith-aged and younger Archean-aged groupings

Samples 622 and 260 produced one population with a $^{207}\text{Pb}/^{206}\text{Pb}$ date comparable to the inferred protolith age, and one population that gives a younger Archean age.

Sample 622: strongly altered dacite, underground grab sample, associated with V1-V2-V4 veining.

A total of 367 zircon grains were picked, mounted, and polished, and 88 were analyzed. These 88 analyses can be split into two groups, Groups 1 and 2. Group 1, consisting of 59 analyses, gives a date range of ~2697 to 2772 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2740 Ma. Analyses are clustered on a Tera-Wasserburg concordia diagram (Figure 4.26) where some are weakly discordant, weakly reverse discordant, and some analyses are concordant. Group 1 zircon grains are subhedral and some have euhedral pointed tips. Most grains display oscillating discrete zoning; however, some have homogenous zones (Figure 4.24). Sample 622 also produced one zircon grain with a $^{206}\text{Pb}/^{238}\text{U}$ date of 1043 ± 8 Ma; this grain will be discussed in Section 4.2.4.2.

Group 2 consists of 29 analyses that gives a date range of ~2594 to 2682 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ average age of ~2632 Ma. Most analyses are weakly to moderately discordant on a Tera-Wasserburg concordia diagram and some are concordant (Figure 4.26). Group 2 grains display different CL patterns than the Group 1 zircons. Most Group 2 analyses are on the tips of zircon grains that are very dark grey to black in CL, and these tips typically come to prismatic terminations. In comparison, Group 1 zircon grains do not have sharp tips, and are a lighter grey in CL colour (Figure 4.24).

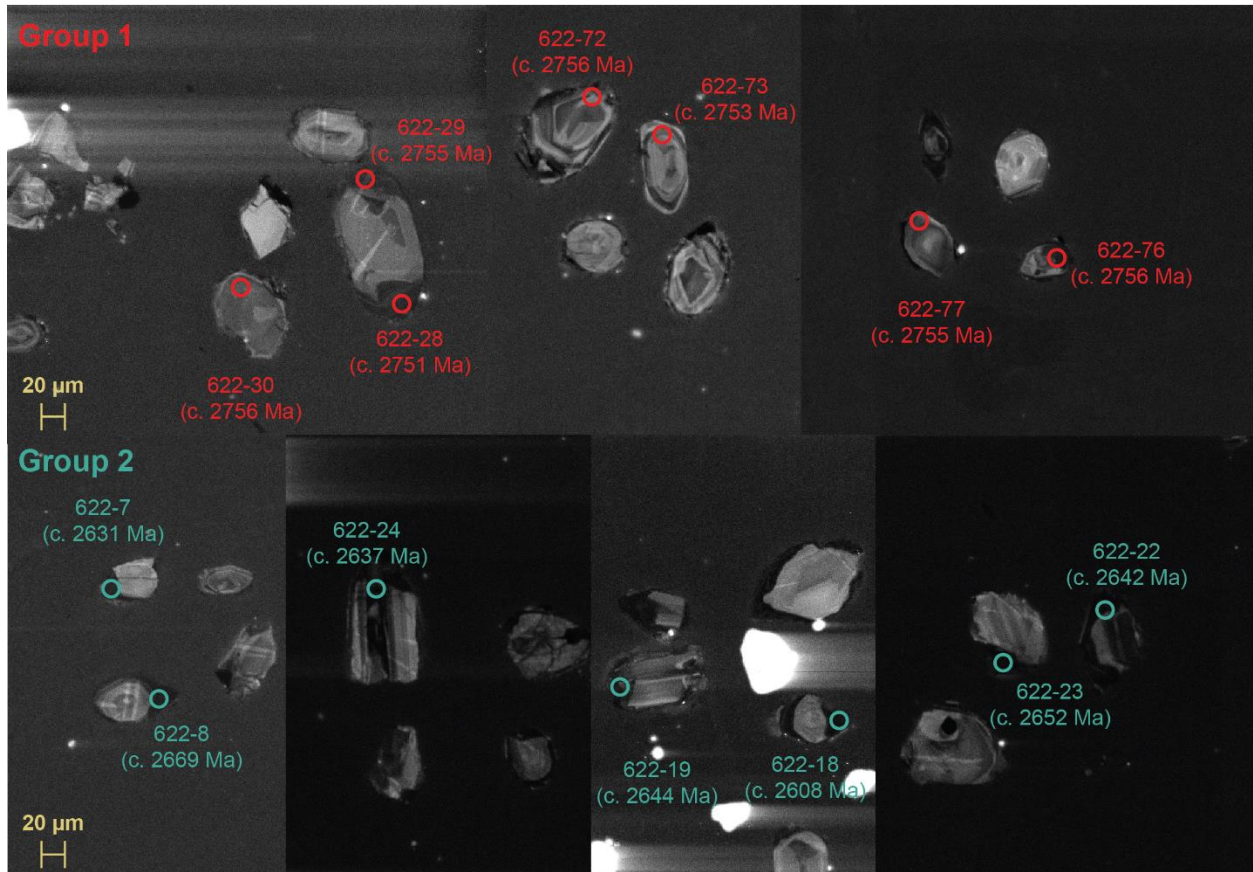


Figure 4.24: CL images of 7 representative zircon grains analysed from sample 622, Group 1 (red labels) and 7 spots from Group 2 (blue labels). Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 260: moderately altered dacite, underground grab sample, associated with barren N-S oriented quartz vein.

A total of 116 zircon grains were picked, mounted, and polished, and 94 were analyzed. These analyses produced two groups of ages, Groups 1 and 2.

Group 1 consists of 44 analyses that give a date range of ~2758 to 2723 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2739 Ma. This group of analyses cluster on a Tera-Wasserburg concordia diagram where some analyses are concordant, and some are reverse discordant (Figure 4.26). Group 1 zircons are generally subhedral with discrete oscillatory internal zonation, ranging from light to medium grey in CL (Figure 4.25).

Group 2, consisting of 48/50 analyses, gives a date range of ~2673 to 2718 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2697 Ma. Analyses are clustered on a Tera-Wasserburg concordia diagram; some analyses are weakly reverse discordant, and some analyses are concordant (Figure 4.26). Zircon grains for Group 2 are typically subhedral to rounded with bright, homogenous zonation, as opposed to the oscillatory zonation of Group 1 grains (Figure 4.25).

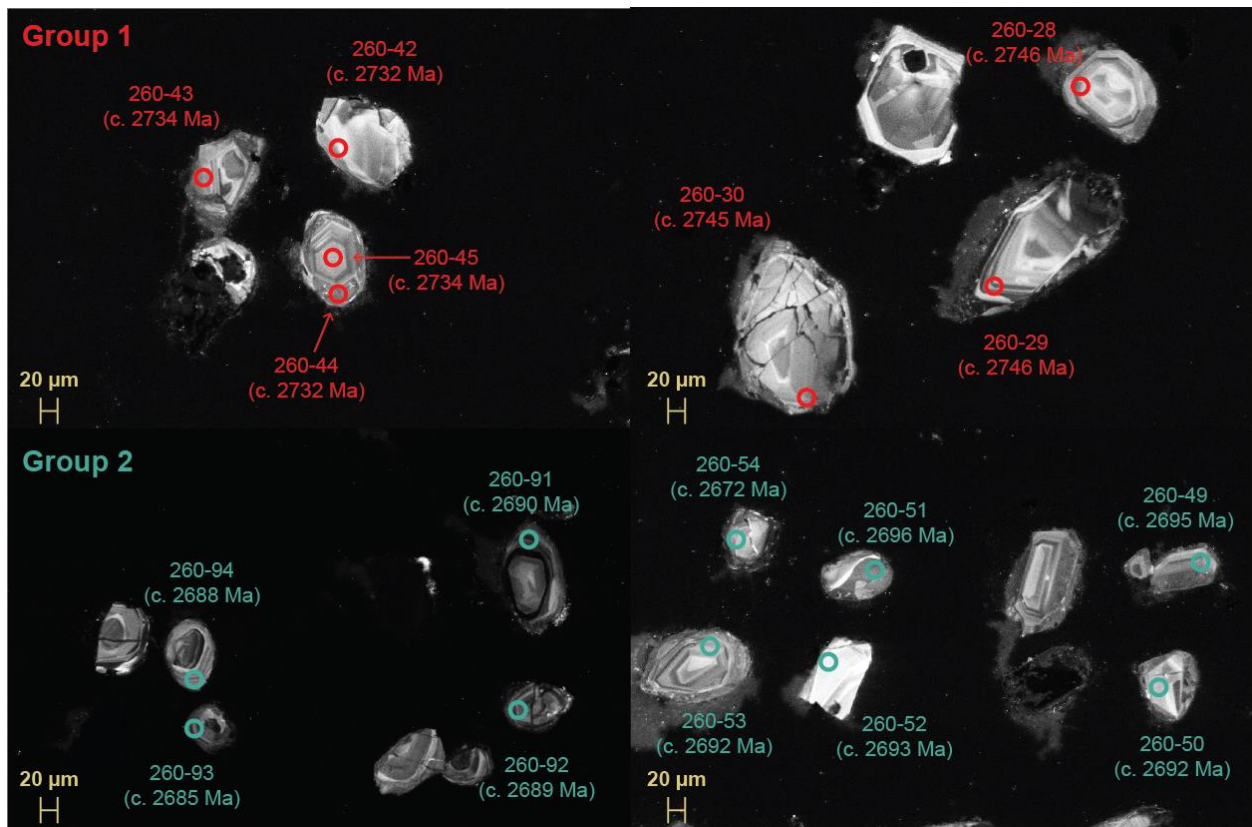


Figure 4.25: CL images of 7 representative zircon grains analysed from sample 622, Group 1 (red labels) and 10 grains from Group 2 (blue labels). Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

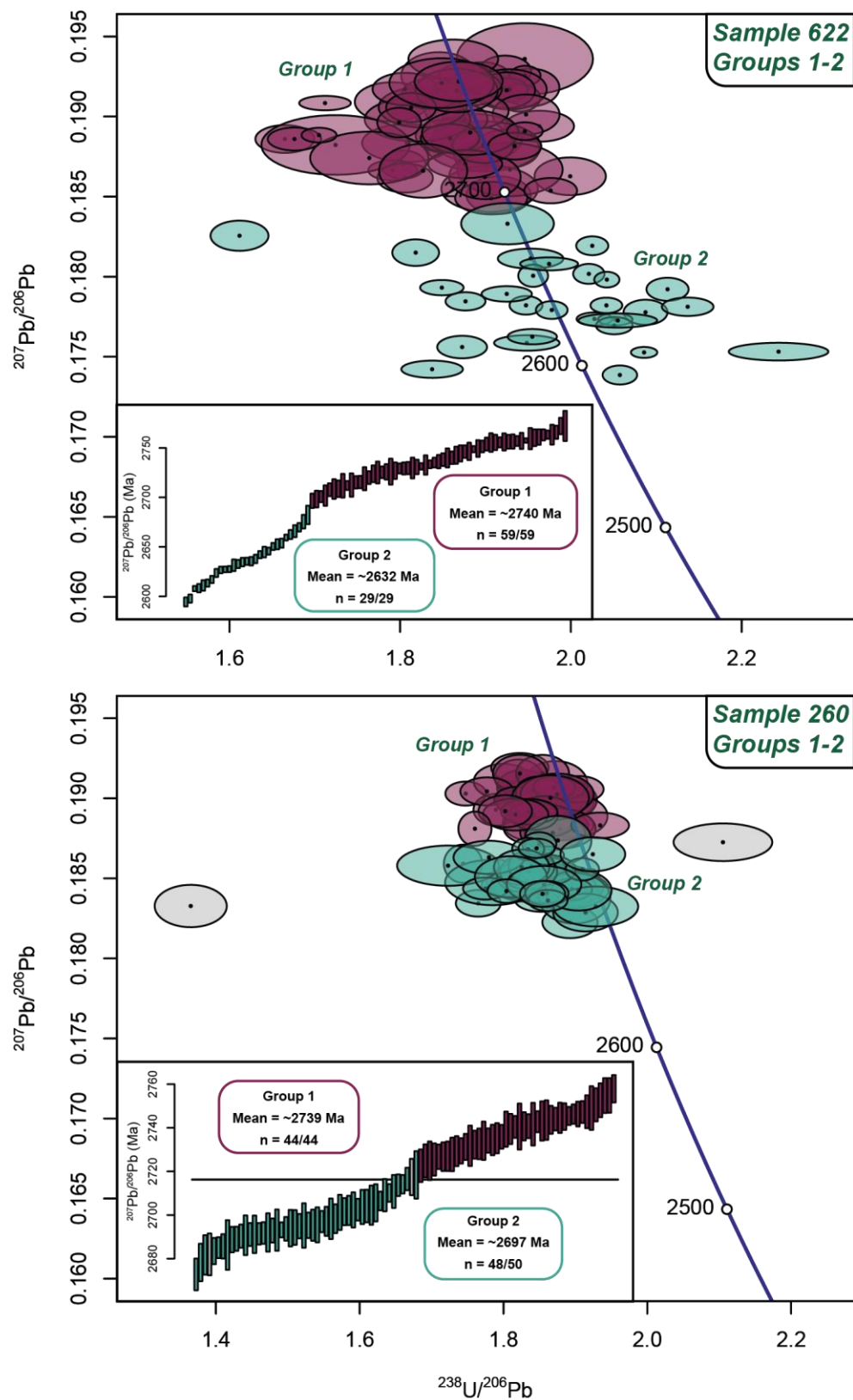


Figure 4.26: Concordia and weighted mean diagrams of samples 622 and 260. Approx. $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean ages and the number of grains included in the calculation for each sample are listed. Ellipses and bars in red or green are analyses included in the weighted mean age calculation, and those in grey were omitted.

4.2.3.2 Young Archean Age Groups

Five samples give average $^{207}\text{Pb}/^{206}\text{Pb}$ ages that are Archean but are younger than the inferred protolith age of ~ 2735 Ma. Samples 261, 262, 263, 264, and 266 give ages between ~ 2640 Ma to ~ 2710 Ma. All samples except sample 262 have two populations of dates, and each subset will be discussed and compared below.

Sample 261: strongly altered dacite, underground grab sample, associated with V1-V2-V3-V4 veining.

A total of 59 zircon grains were picked, mounted, and polished, and 38 were analyzed, producing two populations of dates. Group 1, consisting of 9/11 analyses, gives a date range of 2673 to 2648 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2670 Ma. Zircon grains for Group 1 are ~ 60 - 80 μm and are subhedral to round with medium grey, homogenous zonation (Figure 4.27). On a Tera-Wasserburg concordia diagram, all analyses of Group 1 are reversely discordant and display vertically stretched error ellipses and there is a vertical spread between analyses, indicating a larger error in the $^{207}\text{Pb}/^{206}\text{Pb}$ ratios than the $^{238}\text{U}/^{206}\text{Pb}$ ratios (Figure 4.31). This larger $^{207}\text{Pb}/^{206}\text{Pb}$ ratio error and the reverse discordance of all analyses indicate that these results may not be geologically significant.

Group 2 consists of 27/27 zircon analyses, giving a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~ 2712 Ma. Group 2 zircons are between ~ 40 - 60 μm and are slightly smaller than the Group 1 zircons. Group 2 zircons are subhedral to rounded, and most show distinct oscillatory zonation and are a medium grey colour (Figure 4.27). Group 2 analyses cluster together on a Tera-Wasserburg concordia diagram and all are moderately reversely discordant (Figure 4.31).

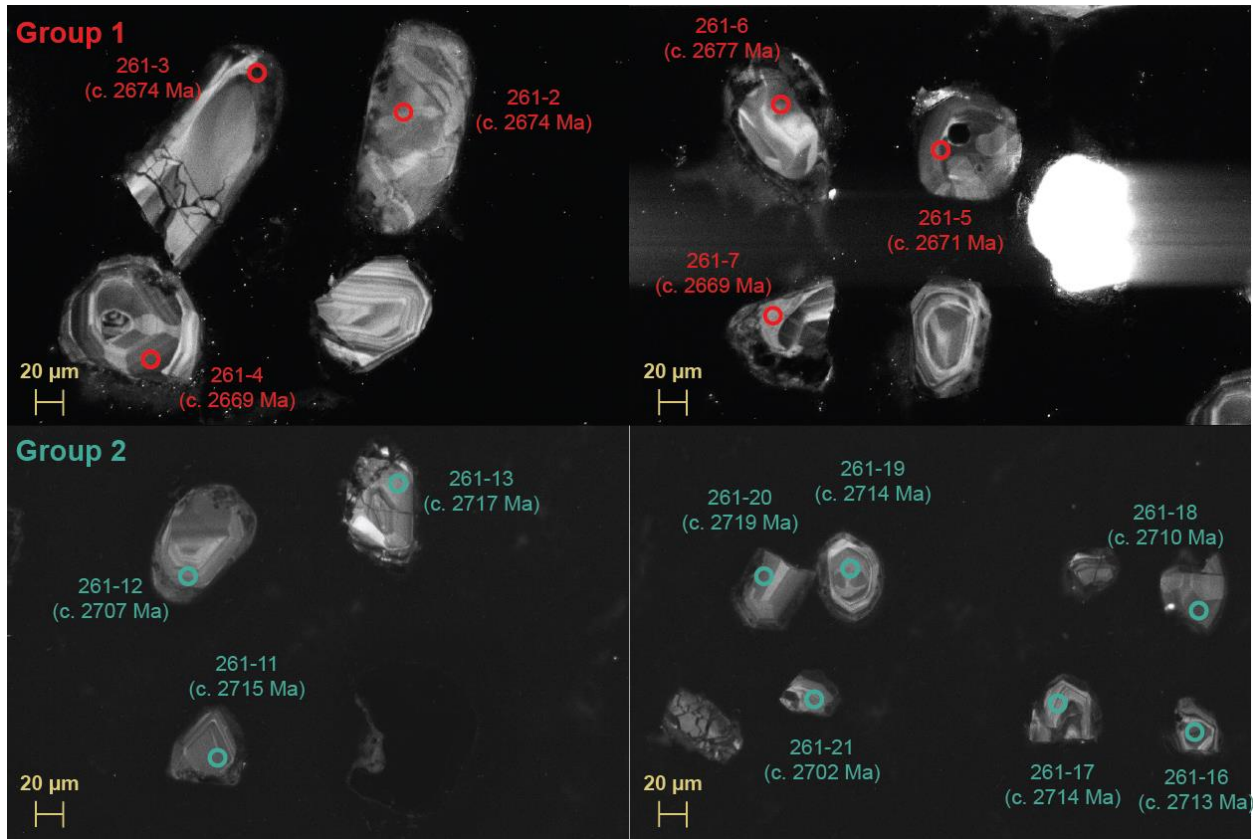


Figure 4.27: CL images of 6 zircon grains from sample 261, Group 1 (red labels) and 9 zircons from Group 2. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 263: strongly altered dacite, underground grab sample, associated with V1-V2-V4 veining.

A total of 42 zircon grains were picked, mounted, and polished, and 34 were analyzed, producing two populations of dates, Groups 1 and 2. Group 1, consisting of 7/7 analyses, gives a date range of ~2645 to 2628 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2641 Ma. Zircon grains for Group 1 are ~40-60 µm and are subhedral to round with a medium grey CL colour and a mixture of homogenous zonation and thick oscillatory zonation (Figure 4.28). On a Tera-Wasserburg concordia diagram, all analyses are reversely discordant (Figure 4.31).

Group 2 consists of 27/27 analyses, giving a date range of ~2703 to 2663 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2675 Ma. Group 2 grains are subhedral to rounded, most

show light grey homogenous/patchy zoning (Figure 4.28). Analyses cluster together on a Tera-Wasserburg diagram, all are reversely discordant, and there is a small degree of vertical spread between analyses (Figure 4.31).

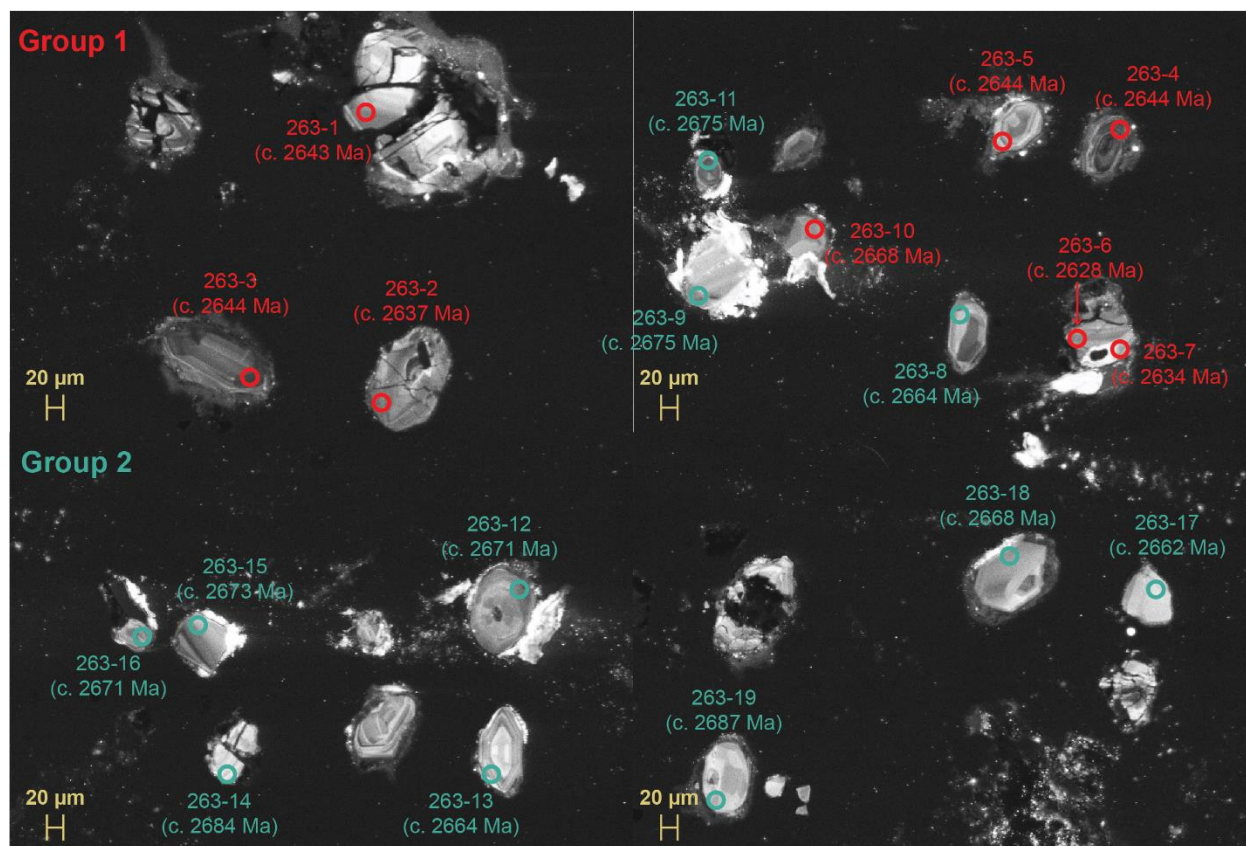


Figure 4.28: CL images of all 7 zircon grains analysed from sample 263, Group 1 (red labels) and 8 spots from Group 2 (blue labels). Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 264: strongly altered dacite, underground grab sample, associated with V1-V2-V4 veining.

A total of 41 zircon grains were picked, mounted, and polished, and 29 were analyzed, which produced two populations of dates, Groups 1 and 2. Group 1, consisting of 18/18 analyses, gives a date range of ~2683 to 2663 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2670 Ma. Zircon grains for Group 1 are ~40 μm and can be up to ~60-80 μm in length for prismatic grains. Most are subhedral with pointed ends and a small number are round. They are light grey in CL

and show minimal zonation; most display homogenous zones with a minor difference in colour between the cores and rims (Figure 4.29). On a Tera-Wasserburg concordia diagram, most analyses are reversely discordant (Figure 4.31).

Group 2 consists of 11/11 analyses, giving a date range of ~2706 to 2693 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2696 Ma. Most Group 2 grains ~40 μm and are primarily rounded, however a small number are elongate and prismatic. Most show light grey homogenous zoning in CL and the elongate grains show oscillatory zoning (Figure 4.29) Analyses cluster together on a Tera-Wasserburg diagram, and all are weakly reversely discordant (Figure 4.31).

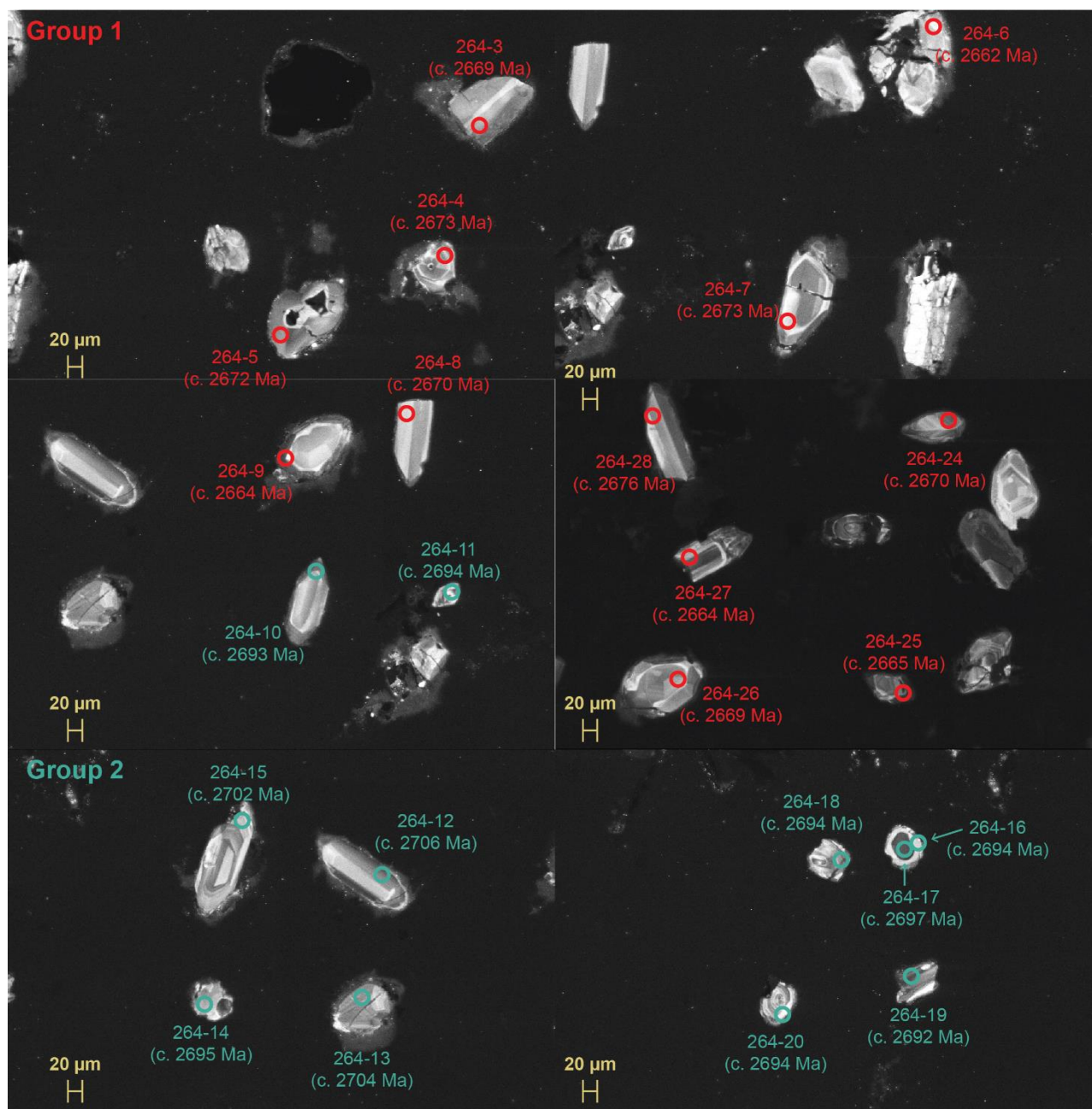


Figure 4.29: CL images of 12 zircon grains analysed from sample 264, Group 1 (red labels) and 8 grains from Group 2 (blue labels). Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

Sample 266: strongly altered dacite, underground grab sample, associated with V1-V2-V4 veining and a N-S oriented quartz-tourmaline vein.

A total of 70 zircon grains were picked, mounted, and polished, and 24 were analyzed which produced two populations of dates, Groups 1 and 2. Group 1, consisting of 14/15 analyses,

gives a date range of ~2671 to 2625 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2652 Ma.

Zircon grains for Group 1 are ~40 μm and can be up to ~60-80 μm in length for prismatic grains. Most are subhedral with prismatic ends and a small number are round. They are light grey in CL and show minimal zonation; most display homogenous zones with a minor difference in colour between the cores and rims (Figure 4.30). On a Tera-Wasserburg concordia diagram, most analyses are reversely discordant and there is moderate vertical spread between analyses (Figure 4.31).

Group 2 consists of 9/9 analyses, giving a date range of ~2725 to 2692 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2711 Ma. Most Group 2 grains are ~40-55 μm and are subhedral, some are elongate and prismatic, and some are rounded. Most show light grey homogenous zoning in CL except the elongate grains which show faint oscillatory zonation (Figure 4.30). Analyses cluster together on a Tera-Wasserburg diagram; some are weakly reversely discordant, and some are concordant (Figure 4.31).

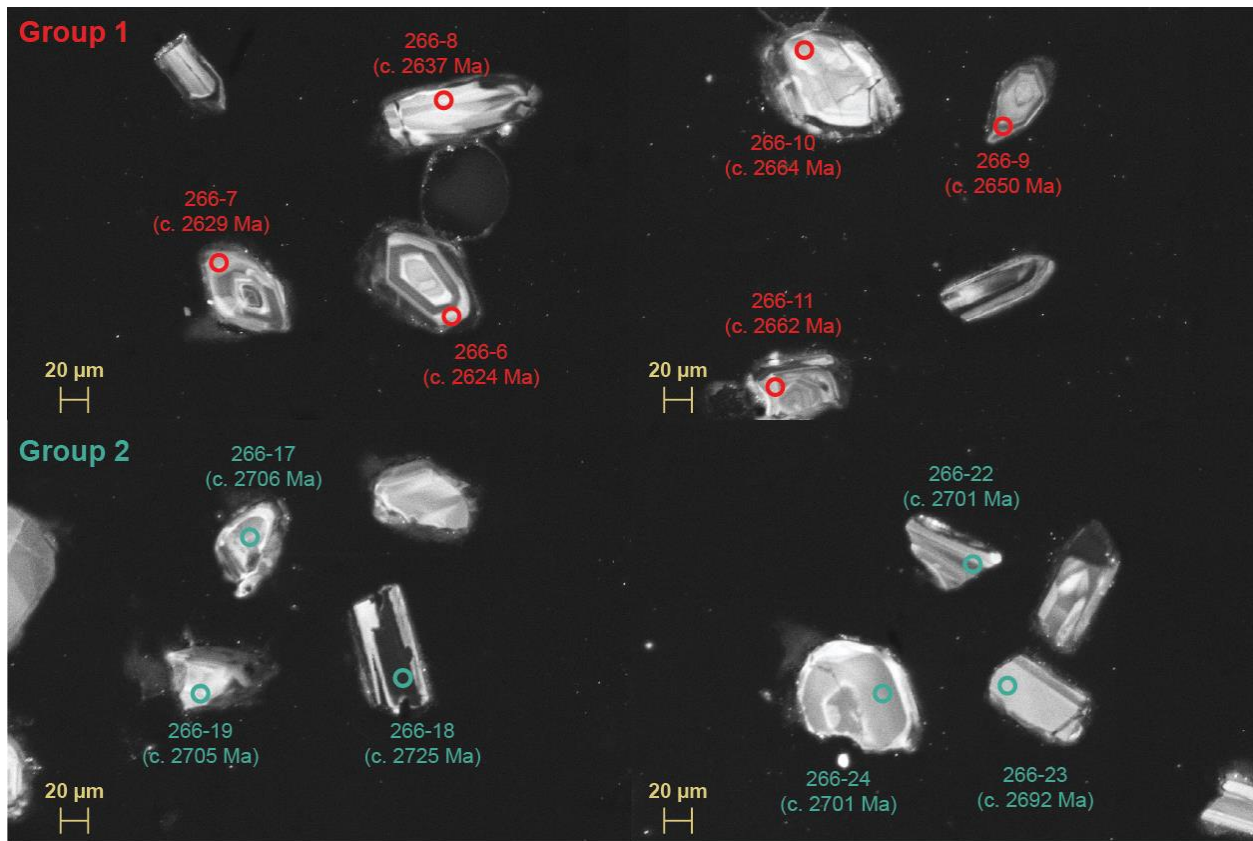


Figure 4.30: CL images of 6 zircon grains analysed from sample 266, Group 1 (red labels) and 6 from Group 2 (blue labels). Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

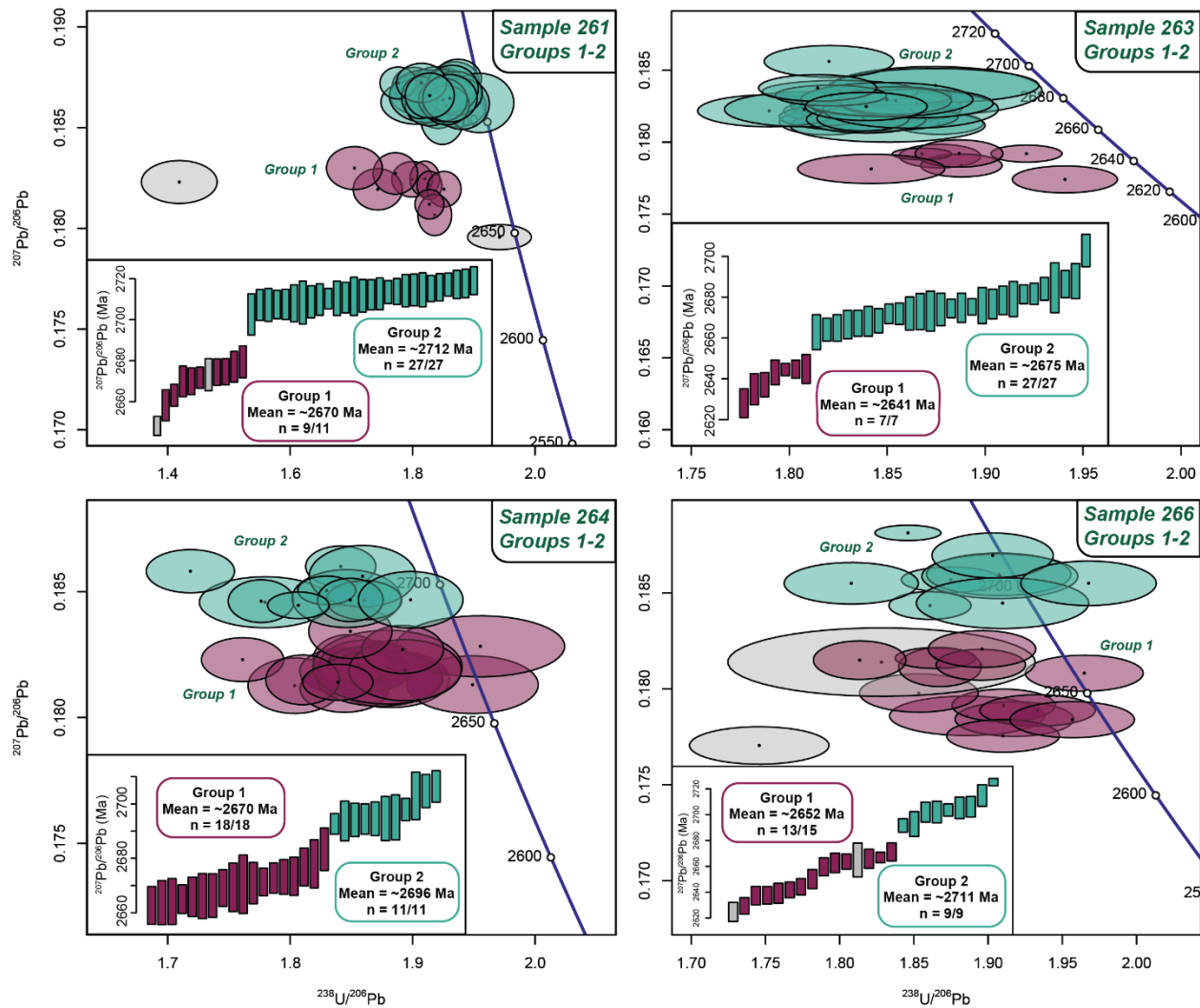


Figure 4.31: Concordia and weighted mean diagrams of samples 261, 263, 264, and 266. Approx. $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean dates and the number of grains included in the calculation for each sample are listed. Ellipses and bars in red or green are analyses included in the weighted mean age calculation, and those in grey were omitted.

Sample 262: strongly altered dacite, underground grab sample, associated with V1-V2-V4 veining.

A total of 33 zircon grains were picked, mounted, polished, and analyzed. Sample 262 gives one date population with a date range of ~2667 to 2620 Ma and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of ~2642 Ma. The grains range in size from ~40 μm up to ~90 μm for those with elongate prismatic habit. Most grains are subhedral, and a light to medium grey in CL with homogenous/patchy zonation or weak zoning (Figure 4.32). On a Tera-Wasserburg concordia

diagram, all analyses are reversely discordant and display slight vertical spread between analyses (Figure 4.33).

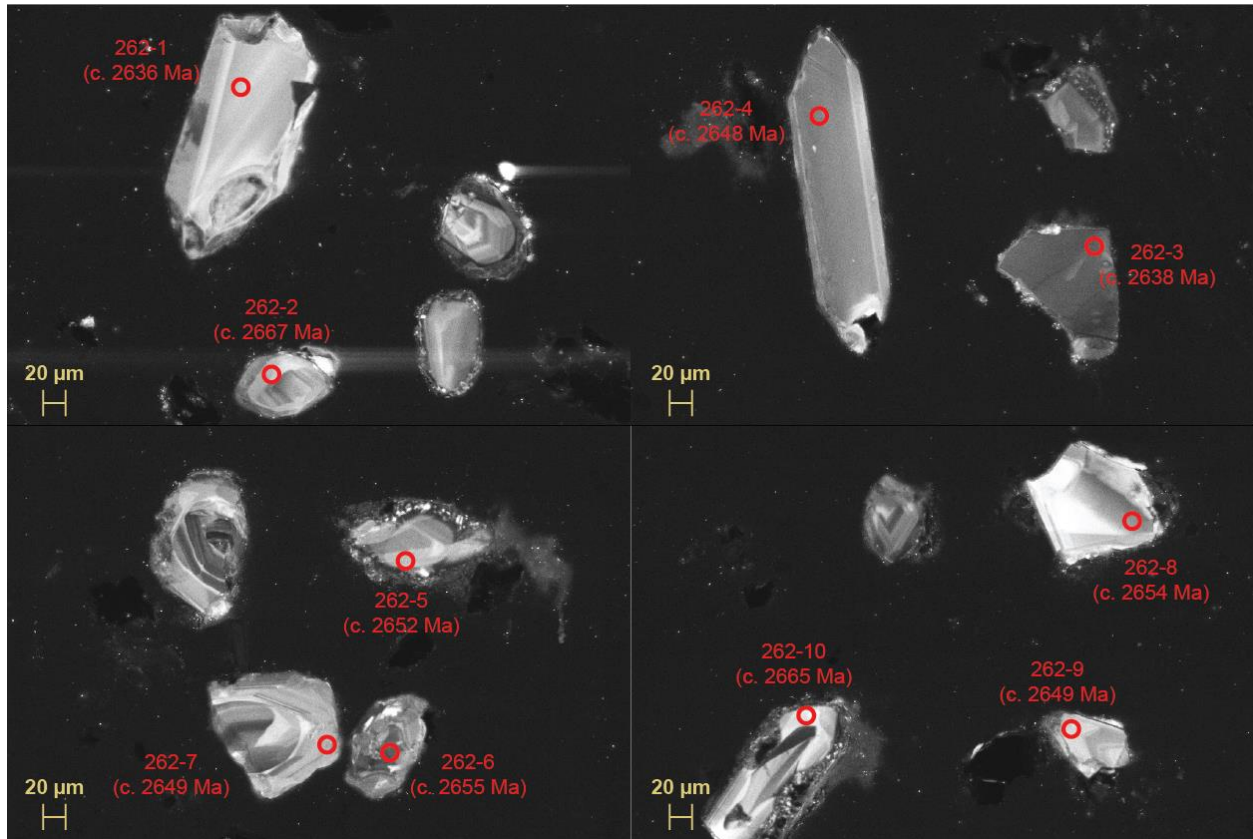


Figure 4.32: CL images of 12 zircon grains analysed from sample 262. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

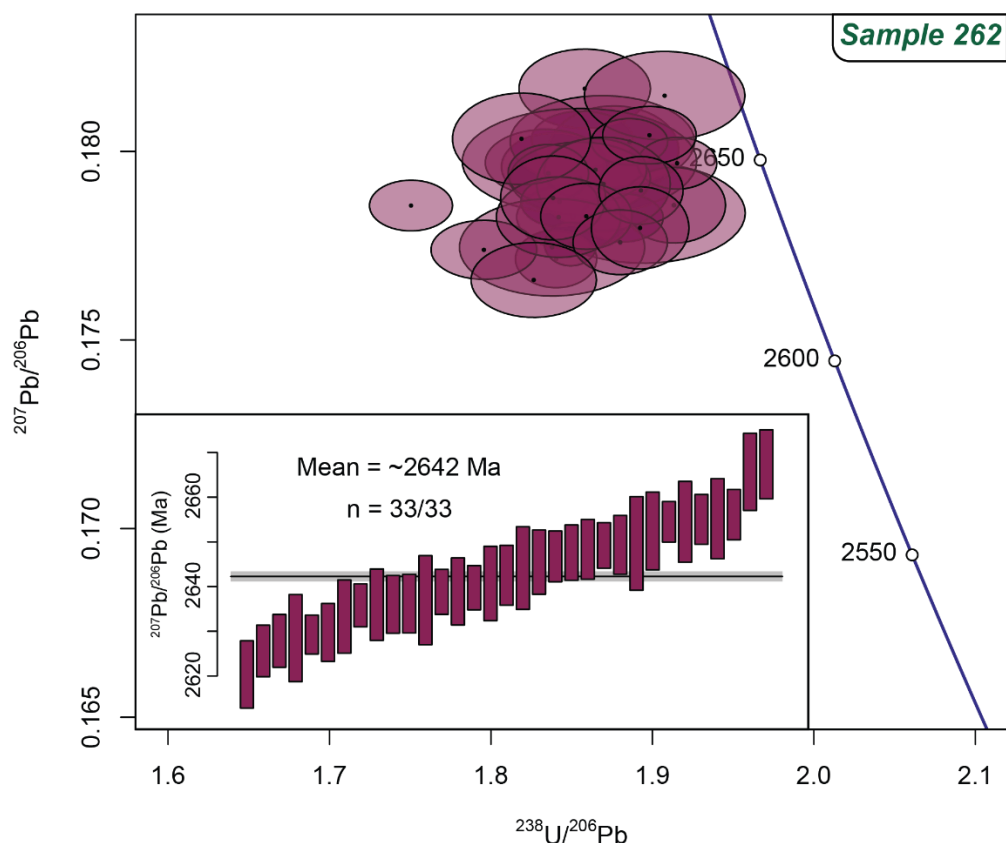


Figure 4.33: Tera-Wasserburg concordia diagram and $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean diagram for sample 262. Average $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean date and number of grains is given.

Sample 628: carbonatite

Sample 628 is an above ground outcrop sample of a carbonatite, located to the west of Island Gold mine, adjacent to the Magino mine (Figure 2.2). Carbonatite is found within drill core in the mine, and it is assumed that the carbonatite at surface is related to the carbonatite within the drill core.

Fifteen zircon grains were analyzed from sample 628, and produced two populations of ages, Groups 1 and 2. Group 1 gives $^{207}\text{Pb}/^{206}\text{Pb}$ ages between ~1362 Ma and ~1419 Ma, and a $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age of c. 1403 Ma; Group 2 gives $^{207}\text{Pb}/^{206}\text{Pb}$ ages between ~2663 Ma to ~2628 Ma, and a mean age of ~2646 Ma. In CL imaging, Group 1 zircons have patchy and weak oscillatory zonation, and Group 2 zircons have mottled internal patterns and no zonation

(Figure 4.34). On a Terra-Wasserburg concordia diagram, Group 1 zircons are all reversely discordant, and Group 2 zircons are discordant to reversely discordant (Figure 4.35).

Group 2 zircons are interpreted to be primary zircons and represent the crystallization age of the carbonatite dyke, due to their unique CL imagery and trace element characteristics (see Section 4.3.4). Group 1 zircons display similar CL zoning to protolith-aged grains of the felsic-intermediate host rocks of the area and have similar trace element concentrations (Figure 4.53), these are interpreted to be xenocrysts (see Section 5.2.2.2).

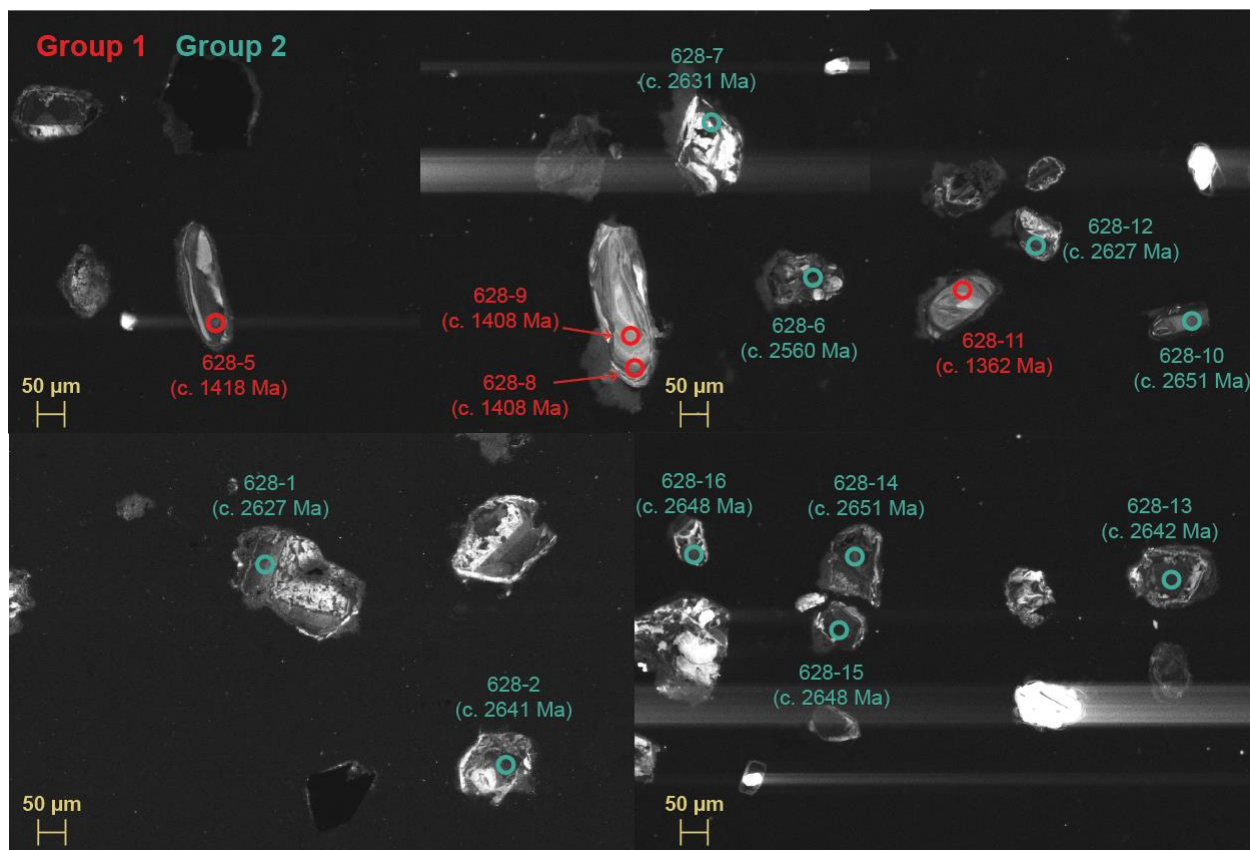


Figure 4.34: CL images of all 3 zircon grains analysed from sample 266, Group 1 (red labels, 4 analysis spots total) and 10 from Group 2 (blue labels). Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

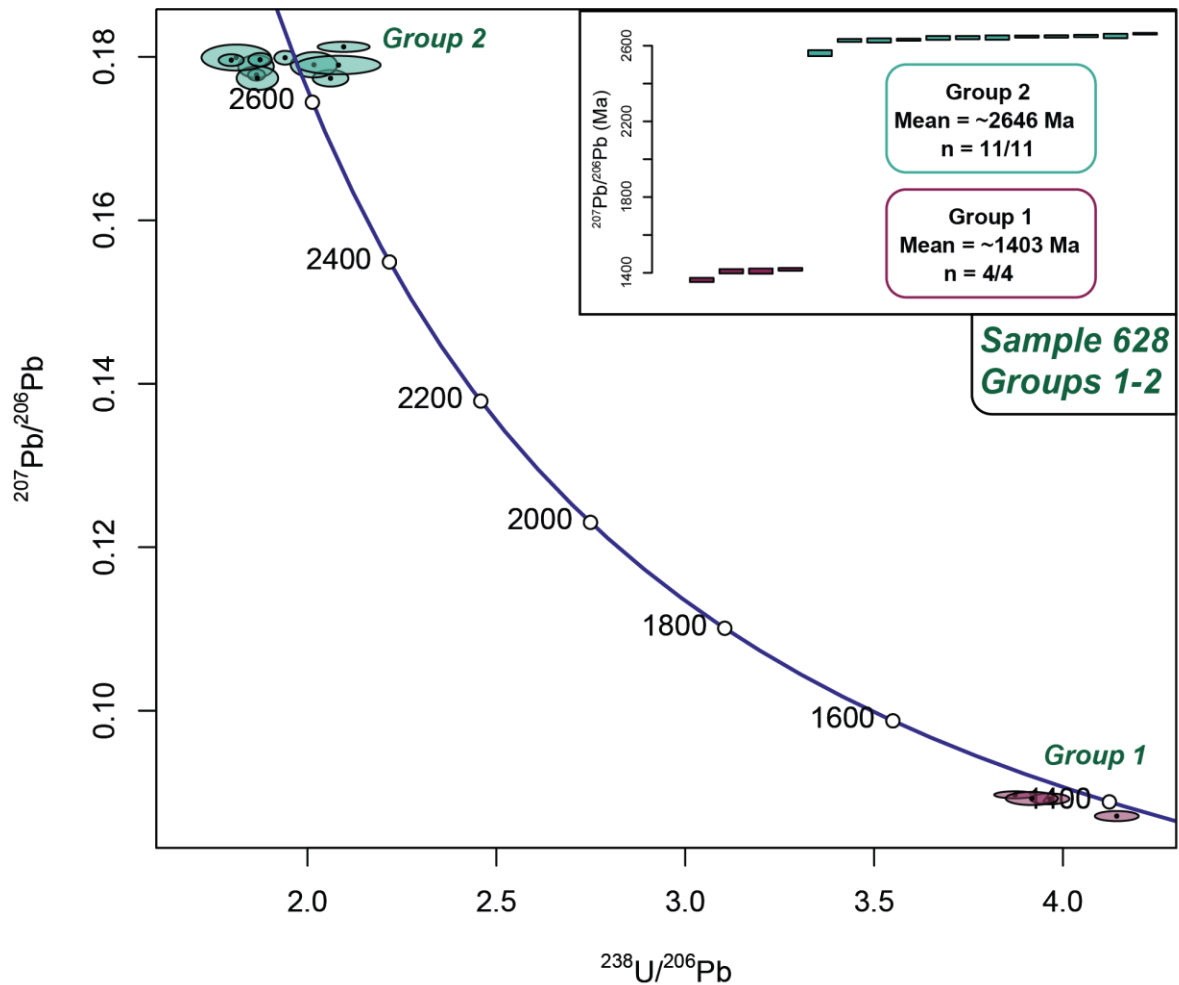


Figure 4.35: Tera-Wasserburg concordia diagram and weighted mean diagram for sample 628 Groups 1 and 2. Average $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean dates and number of grains for each sample group are given.

4.2.4 Archean and Proterozoic to Phanerozoic dates

Three samples contained zircon grains that produced post-Archean dates in addition to a suite of Archean, inferred protolith aged dates. Sample 602 and sample 622 each contained one grain that produced a post-Archean $^{206}\text{Pb}/^{238}\text{U}$ date, and sample 621 contained thirty-one analyses with post-Archean dates. Post-Archean dates are detailed in Section 4.2.4.2.

4.2.4.1 Sample 621 - Archean dates

Sample 621 is a strongly altered dacite associated with auriferous V1-V2 and V4 veining from the main zone of the Island Gold mine. It is dacite wall rock from in-between two veins, a V1-V2 vein and a V1-V2-V4 vein. In thin section, the quartzo-feldspathic groundmass is

strongly altered by white mica and carbonate. Foliation is folded and defined by white mica. Quartz veins are folded and boudinaged (V1-V2) and alternate with bands of strong white mica alteration that include minor tourmaline grains which follow foliation. Anhedral pyrite is present within the white mica alteration bands and along the margins of quartz veins.

A total of 114 zircon grains were separated and 94 were analyzed for U-Pb isotopes. Two populations of dates were found: one Archean in age and comparable to the inferred protolith age of ~2735 Ma (Ciufo, 2019) (discussed below) and a set of analyses that are post-Archean and span from the Proterozoic to Mesozoic (see Section 4.2.4.2).

The protolith-aged population of grains consists of 53/55 analyses and gives a date range of ~2770 – 2700 with an average $^{207}\text{Pb}/^{206}\text{Pb}$ age of c. 2738 Ma. Grains are ~40-60 μm , are subhedral with a mixture of elongate prismatic grains and stubby oval grains, and all are medium-dark grey in CL and show oscillatory zonation (Figure 4.36). All analyses cluster on a Tera-Wasserburg concordia diagram; some are concordant, some are reversely discordant, and some show normal discordance (Figure 4.37). Two of the 55 analyses were omitted from the population of dates as their time-resolved $^{207}\text{Pb}/^{206}\text{Pb}$ ratios were non-flat, indicating the possibility of mixed age domains or the analysis of inclusions.

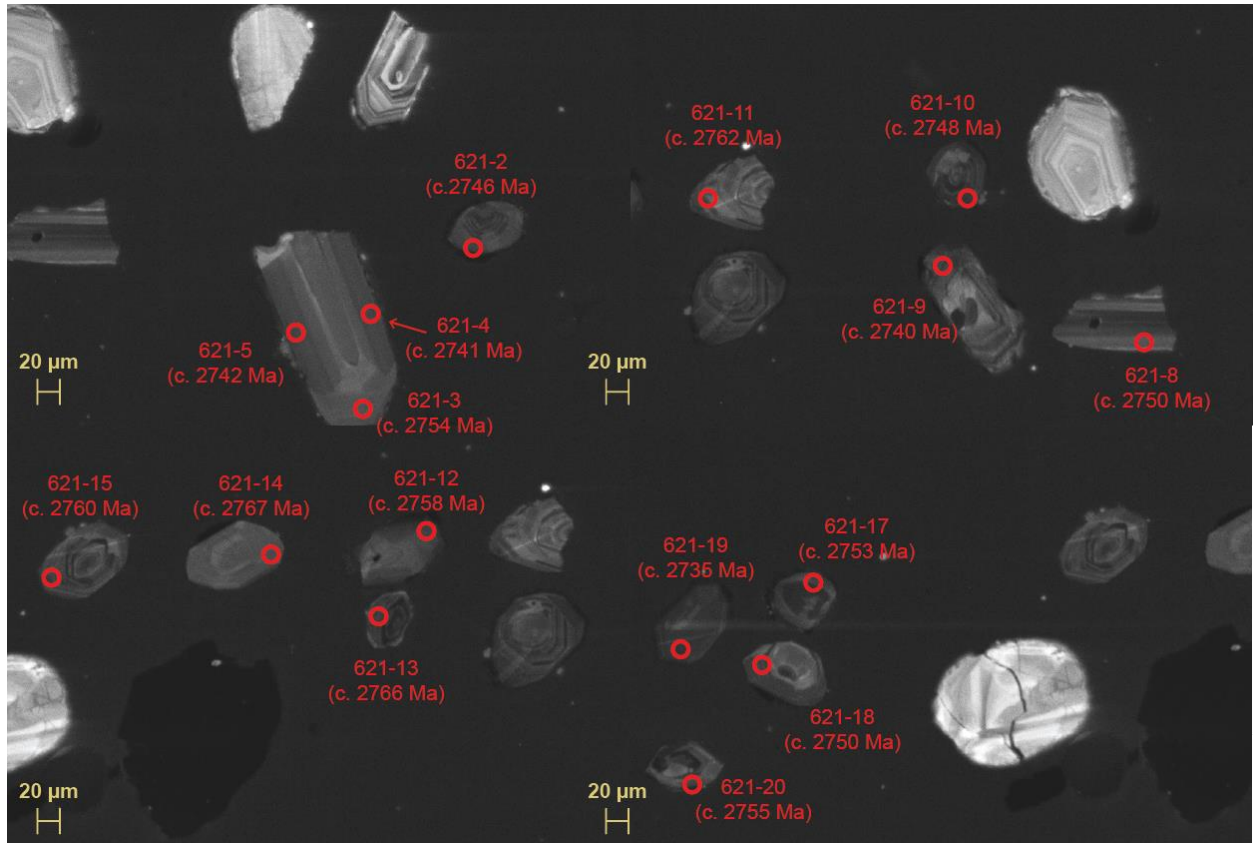


Figure 4.36: CL images of 16 representative zircon grains analysed from sample 621, the protolith-aged population of grains. Spot number and $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given for each analysis point.

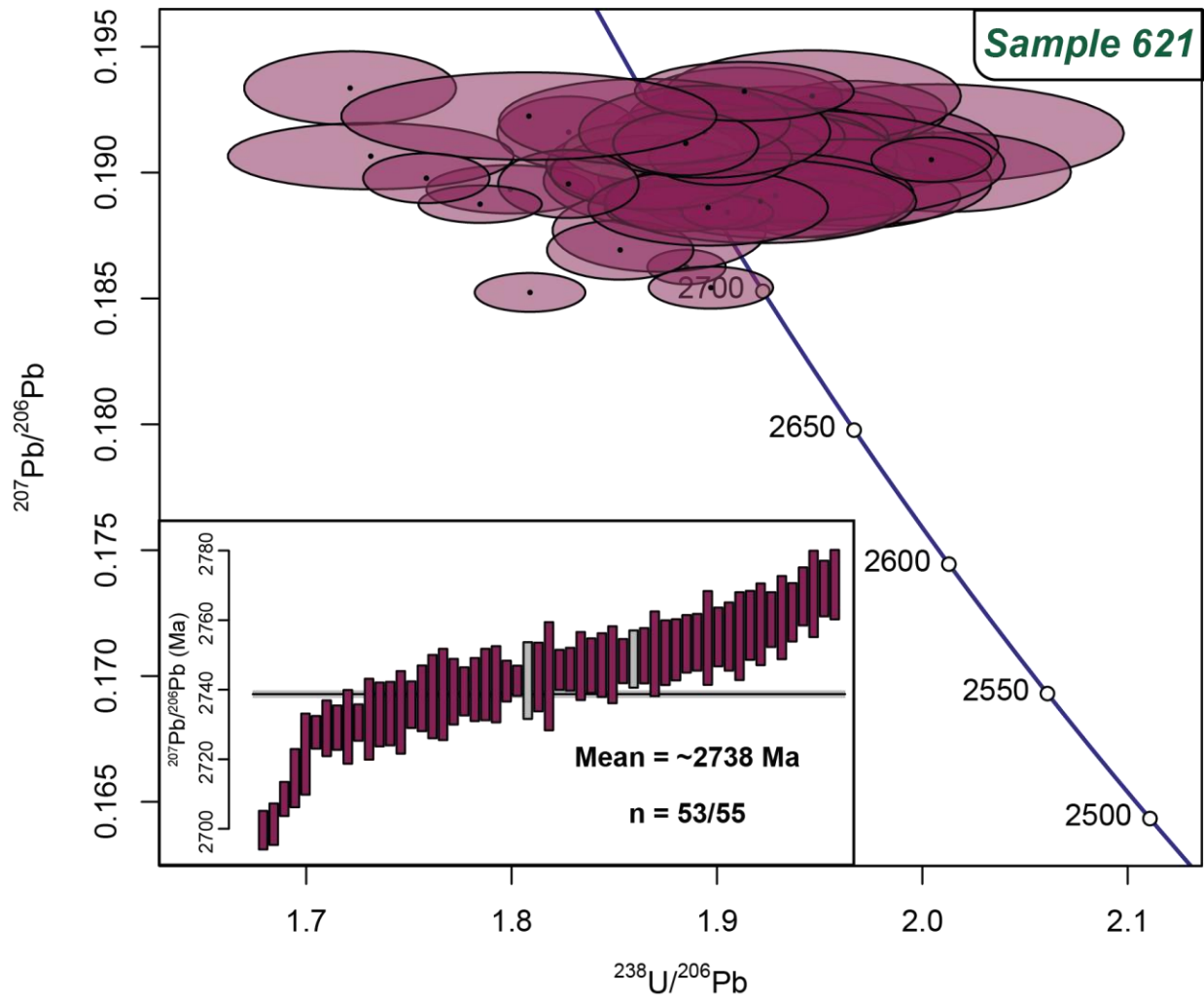


Figure 4.37: Tera-Wasserburg concordia plot and $^{207}\text{Pb}/^{206}\text{Pb}$ weighted mean age diagram for sample 621 with approximate weighted mean, protolith age population. Ellipses and bars in red are analyses included in the weighted mean age calculation, and those in grey were omitted.

4.2.4.2 Post-Archean dates (Proterozoic to Mesozoic)

Three samples contained zircon grains that produced post-Archean dates. Sample 602 contained one grain that produced a $^{206}\text{Pb}/^{238}\text{U}$ date of 502 ± 7 Ma, sample 622 contained one grain that produced a $^{206}\text{Pb}/^{238}\text{U}$ date of 988 ± 11 Ma (Figure 4.38), and sample 621 contained thirty-one analyses with post-Archean dates, with $^{206}\text{Pb}/^{238}\text{U}$ dates ranging from ~ 1138 Ma to ~ 102 Ma (Table 4.5) (Figure 4.39, Figure 4.43, and Figure 4.44). The majority of these dates are discordant to some degree (concordance percentages are given in Table 4.5), and five analyses are concordant.

CL images of all post-Archean grains are given in Figure 4.40, Figure 4.41, and Figure 4.42. The majority of post-Archean grains display bright CL intensities and variable zoning patterns ranging from faint oscillatory zoning to un-zoned regions, as well as patchy zoning, while most Archean-aged grains are dark grey in CL and show strong oscillatory zoning.

Proterozoic dates from a strongly altered sample associated with auriferous V1-V2 veining (sample TY128) were discovered in a previous study by Ciufo, 2019. Proterozoic grains large enough to be re-analyzed from sample TY128 were dated in this study. Eight grains were analyzed, and 5/8 analyses are included here; three analyses were omitted due to drill throughs caused by spot placement on the edges of the grains. The dates produced in this study and in Ciufo (2019) are given in Table 4.4. Methodology for the analyses from Ciufo (2019) differed from this study; Ciufo (2019) used the LA-ICP-MS technology at the Metal Isotope Lab at the University of Waterloo, however Ciufo (2019) used the Agilent 8800 for U-Pb isotope detection with a 25µm spot diameter. Full details on the methodology can be found in Section 3.9 of Ciufo (2019). There are differences in the dates produced between the studies which may be due to the differences in analytical technique and data reduction, however the dates are broadly similar.

Table 4.4: $^{206}\text{Pb}/^{238}\text{U}$ dates of five zircons from sample TY128 of Ciufo (2019).

Sample-spot #	Ciufo (2019)		This study		
	$^{206}\text{Pb}/^{238}\text{U}$ (Ma)	2σ (Ma)	$^{206}\text{Pb}/^{238}\text{U}$ (Ma)	2σ (Ma)	Discordance
TY128-26	1201	35	1080	12	-2.4%
TY128-34	1195	28	1088	11	-1.7%
TY128-42	1260	41	1222	14	-2.4%
TY128-47	1233	23	1132	10	-1.3%
TY128-52	1170	35	1405	14	-0.2%

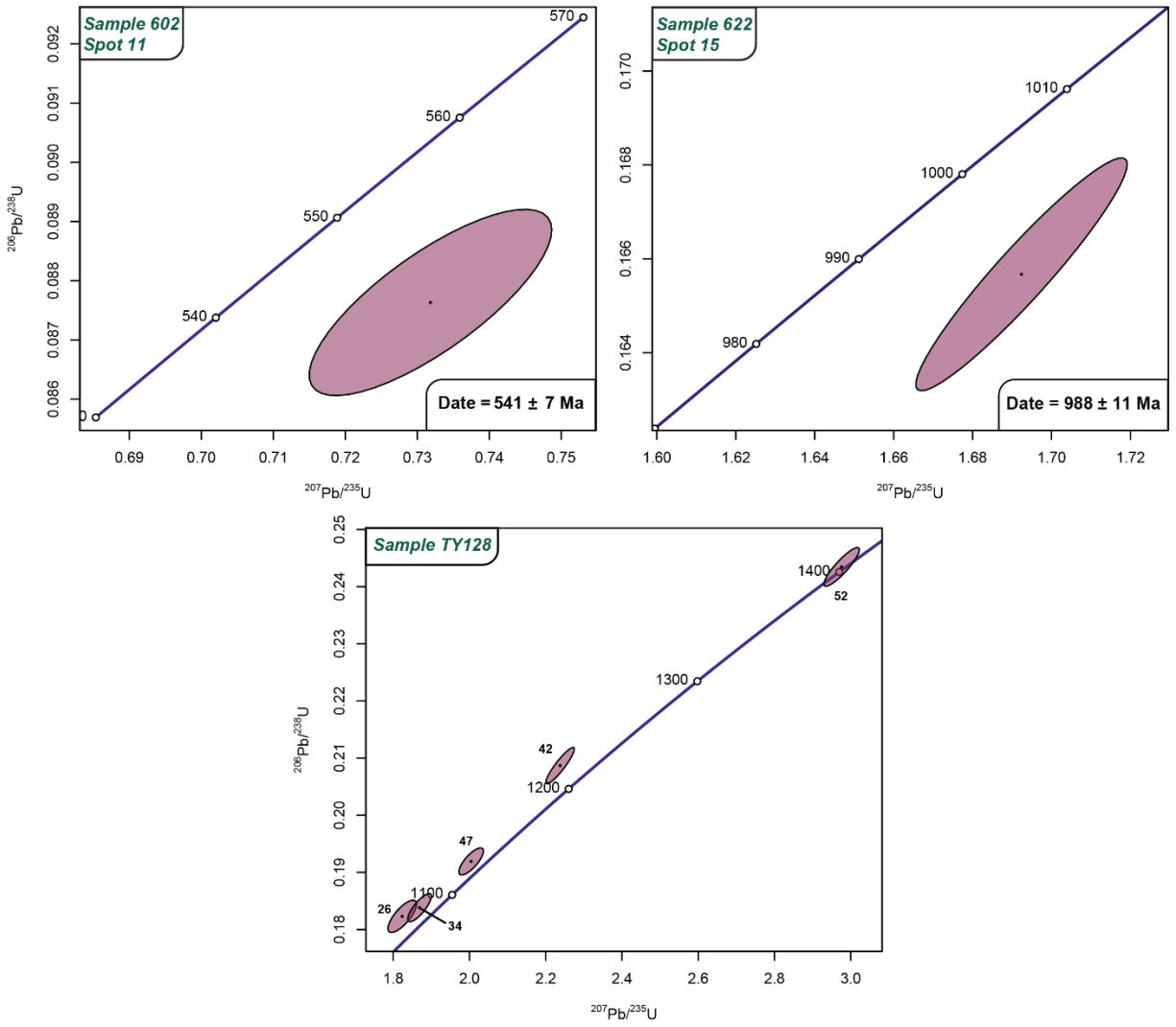


Figure 4.38: Wetherill concordia diagrams of zircon analyses 602-11, 622-15, and analyses from TY-128. Dates given are $^{206}\text{Pb}/^{238}\text{U} \pm 2\sigma$ error.

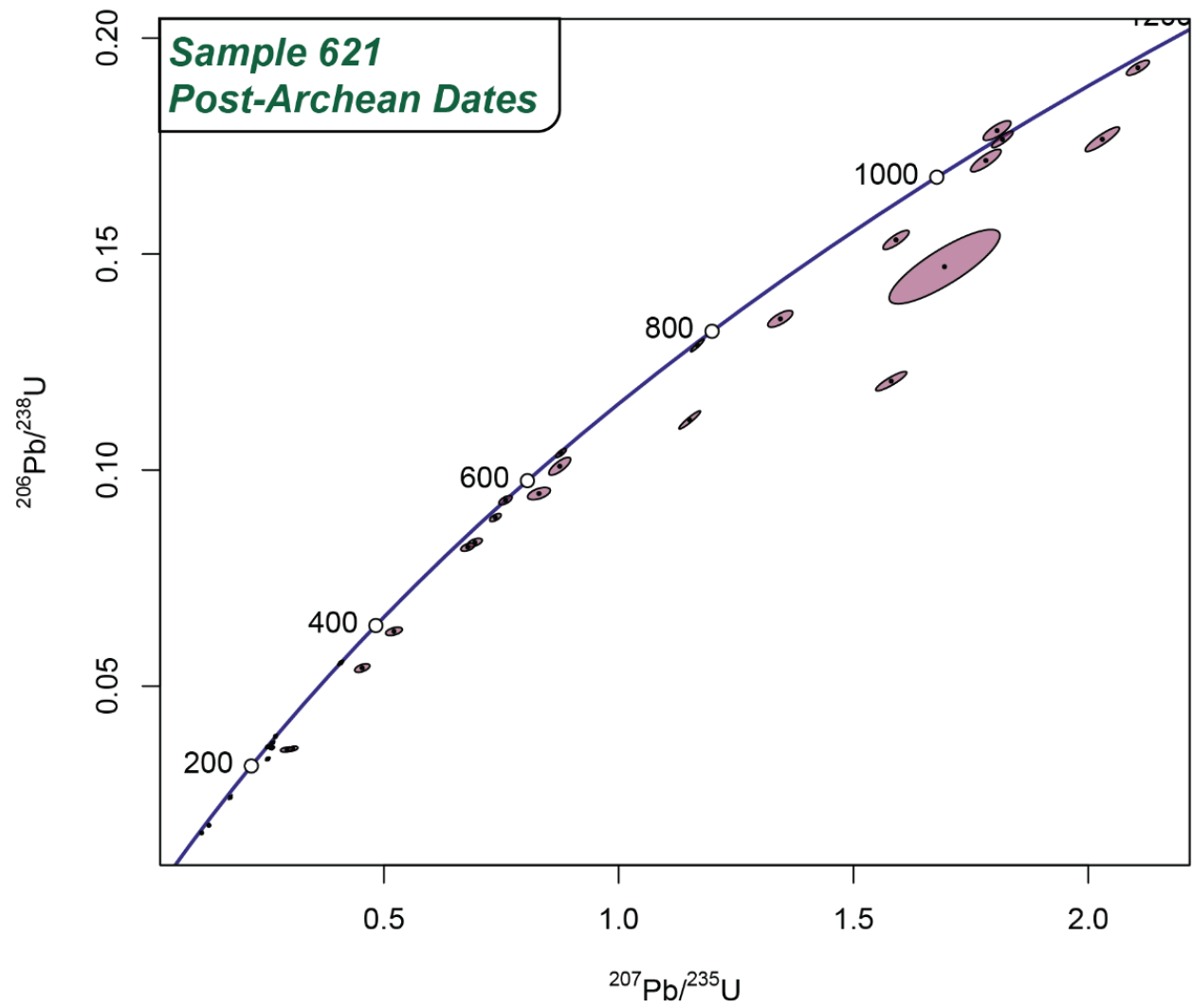


Figure 4.39: Wetherill Concordia diagram of all post-Archean analyses from sample 621.

Table 4.5: Summary of dates for all post-Archean zircon analyses from sample 621, 602, and 622. Dates are given in Ma and the corresponding 2σ error for each is given to the right of each date column. Concordance percentage values ($^{206}\text{Pb}/^{238}\text{U}$ vs $^{207}\text{Pb}/^{235}\text{U}$ dates) for each date are given.

Sample and zircon spot number	$^{207}\text{Pb}/^{235}\text{U}$ (Ma)	2σ (Ma)	$^{206}\text{Pb}/^{238}\text{U}$ (Ma)	2σ (Ma)	$^{207}\text{Pb}/^{206}\text{Pb}$ (Ma)	2σ (Ma)	Concordance (%)
Sample 602							
602-11	557	8	541	8	623	24	2.9%
Sample 622							
622-15	1005	8	988	11	1043	8	1.7%
Sample 621							
621-65	1151	6	1138	8	1174	11	1.1%
621-39	1048	9	1059	10	1023	17	-1.1%
621-56	1126	10	1048	12	1278	13	0.3%
621-60	1052	7	1048	8	1059	10	6.9%
621-69	1039	10	1021	11	1076	16	1.7%
621-31	967	9	919	10	1075	16	4.9%
621-22	1006	36	885	39	1282	59	12.1%
621-29	865	9	816	9	992	22	5.6%
621-85	786	5	781	7	798	7	0.5%
621-32	963	10	734	10	1529	15	23.8%
621-61	778	9	682	10	1063	11	12.3%
621-27	639	5	638	5	646	14	0.3%
621-82	638	10	620	10	704	29	2.9%
621-76	614	11	582	7	731	43	5.1%
621-40	573	7	573	5	573	26	0.0%
621-25	561	6	550	4	607	22	2.0%
621-6	535	7	515	5	620	33	3.7%
621-7	526	7	509	4	600	33	3.2%
621-81*	426	10	392	5	616	53	8.0%
621-57	348	4	347	3	348	18	0.0%
621-37	380	9	340	5	630	53	10.5%
621-86	242	2	243	2	236	11	-0.3%
621-67	237	3	233	2	271	25	2.0%
621-52	229	3	228	2	242	32	1.5%
621-71	236	4	226	2	335	33	0.5%
621-68	271	7	225	3	688	58	3.1%
621-74	261	9	224	3	615	76	4.2%

Sample and zircon spot number	$^{207}\text{Pb}/^{235}\text{U}$ (Ma)	2 σ (Ma)	$^{206}\text{Pb}/^{238}\text{U}$ (Ma)	2 σ (Ma)	$^{207}\text{Pb}/^{206}\text{Pb}$ (Ma)	2 σ (Ma)	Concordance (%)
621-78*	229	3	210	2	424	26	16.9%
621-21*	162	3	155	3	273	10	14.4%
621-88*	122	2	114	1	283	18	6.2%
621-77*	108	2	102	1	223	36	5.3%

Notes: * = analysis point on the edge of grain, should be treated with caution.

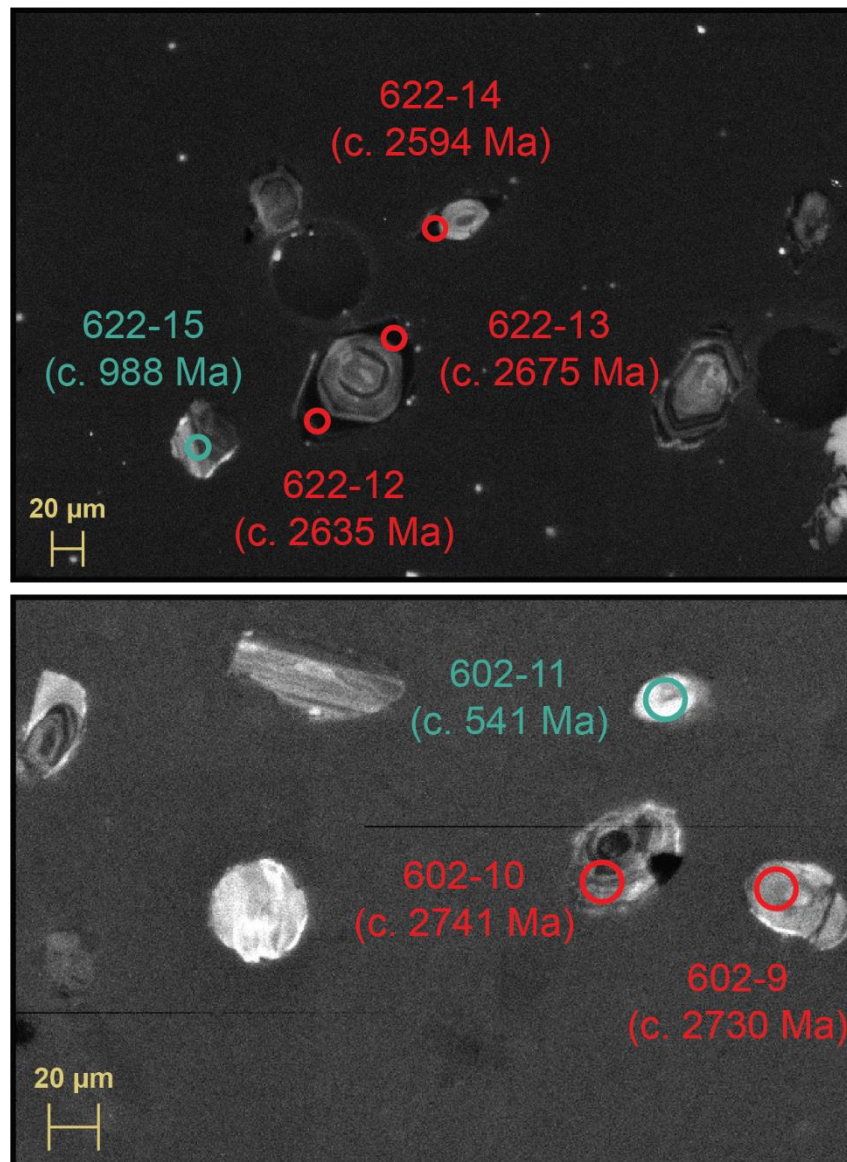


Figure 4.40: CL images of post-Archean zircon grains 602-11 and 622-15 (noted in blue) with approximate $^{206}\text{Pb}/^{238}\text{U}$ dates. Other grains that were dated are labelled in red and their approximate $^{207}\text{Pb}/^{206}\text{Pb}$ dates are given.

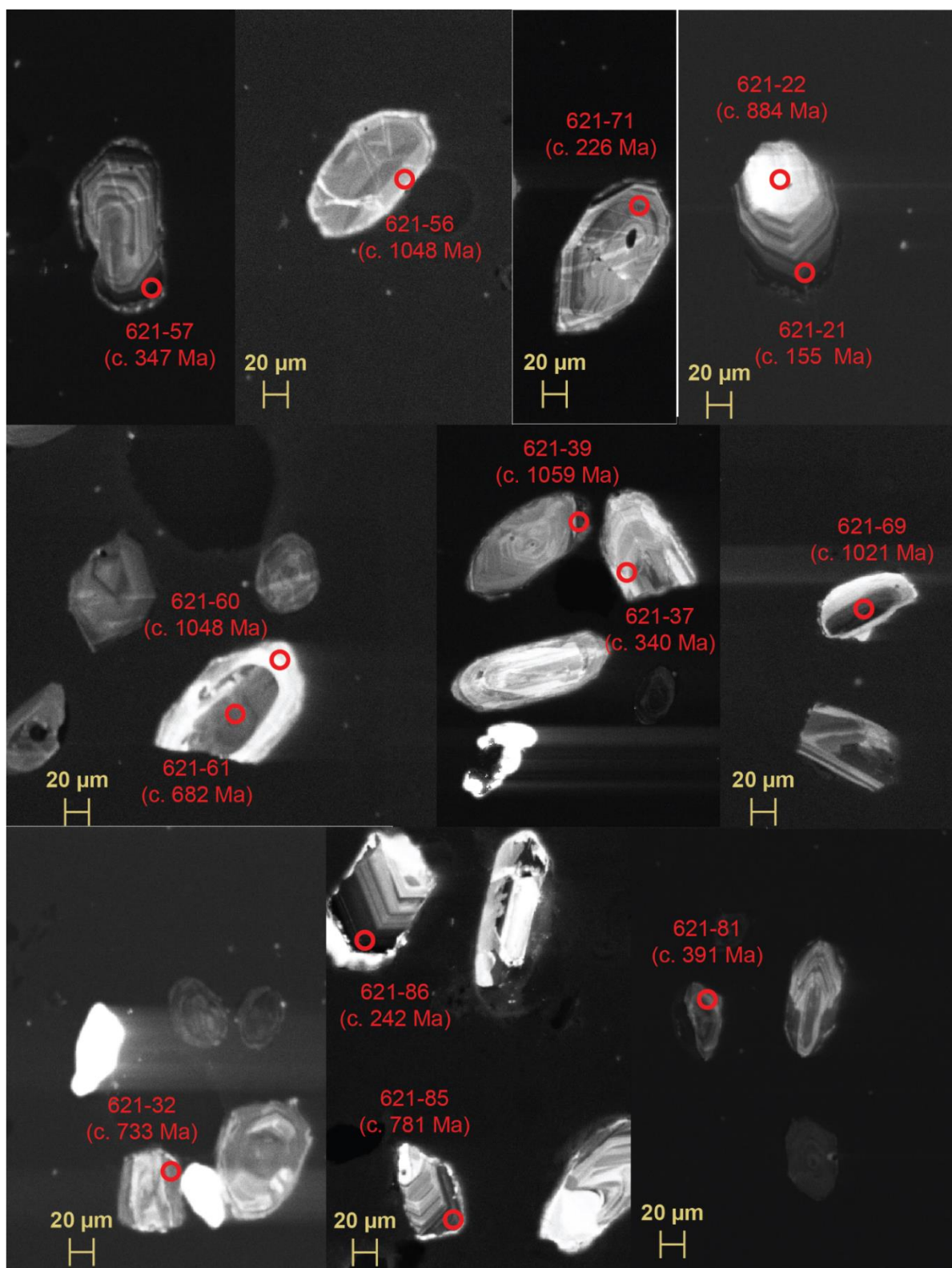


Figure 4.41: Cathodoluminescence images of 14/31 analyses of zircons that give post-Archean dates from sample 621, with approximate $^{206}\text{Pb}/^{238}\text{U}$ dates.

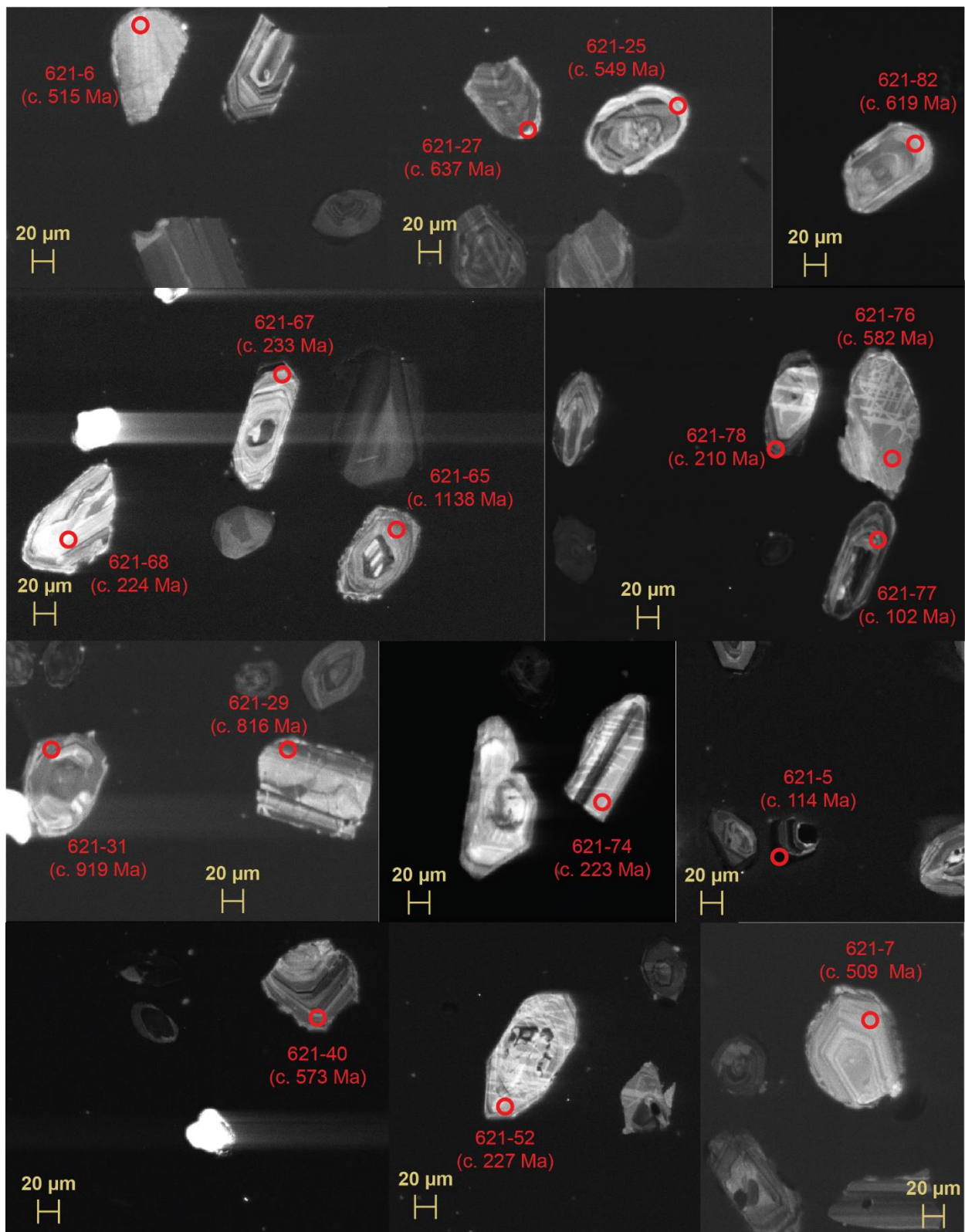


Figure 4.42: Cathodoluminescence images of 17/31 analyses of zircons that give post-Archean dates from sample 621 with approximate $^{206}\text{Pb}/^{238}\text{U}$ dates.

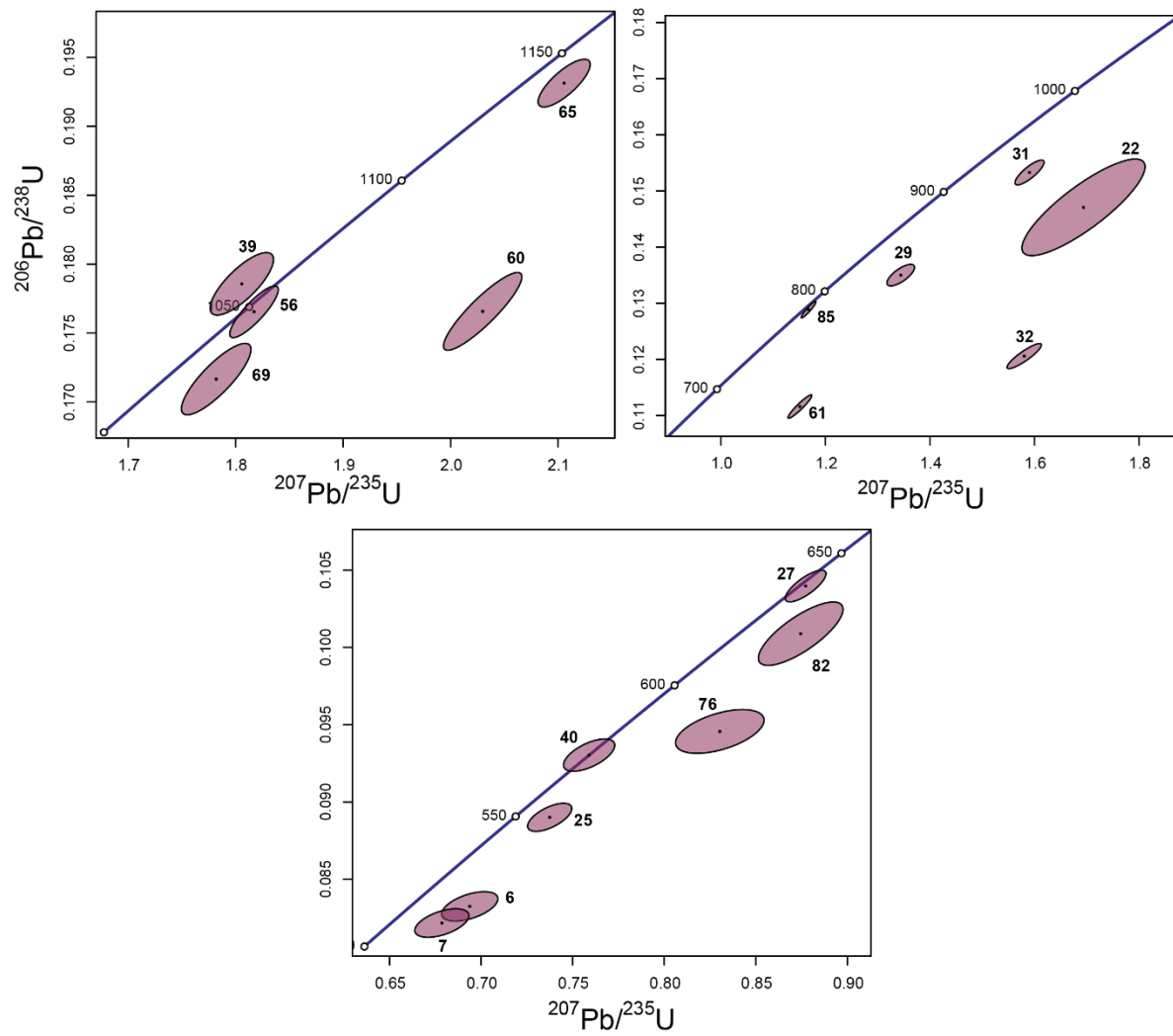


Figure 4.43: Wetherill Concordia diagrams of 18/31 post-Archean dates. $^{206}\text{Pb}/^{238}\text{U}$ dates range from circa 1138 Ma to 509 Ma on these diagrams. Zircon analysis numbers are noted.

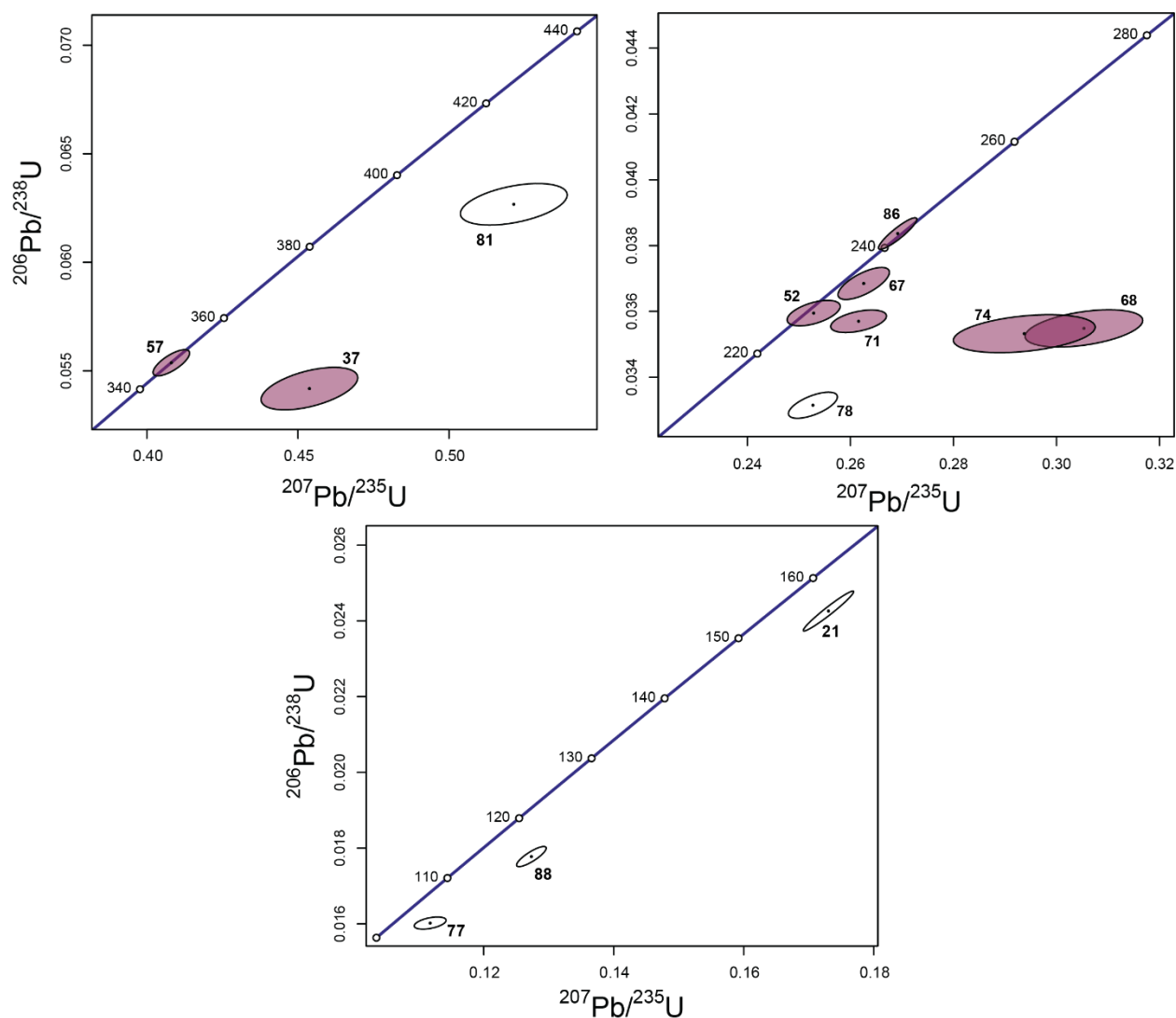


Figure 4.44 Wetherill Concordia diagrams of 13/31 post-Archean dates. $^{206}\text{Pb}/^{238}\text{U}$ dates range from circa 392 Ma to 102 Ma on these diagrams. Zircon analysis numbers are noted. Empty ellipses are analysis spots that were slightly on the edge of the zircon grains (noted with an asterisk in Table 4.5).

4.3 Whole Rock Geochemistry, Stable Isotopes, and Zircon Trace Elements

4.3.1 Whole Rock Geochemistry

All samples were analysed for whole rock lithochemistry and were divided into two different classifications to assess trends associated with age sets and vein types. The vein type classification scheme includes all thirty-two dacite samples and the age set classification includes all eighteen dacite samples discussed in Section 4.2. Major element oxides, trace elements, and chondrite normalized REE plots were created for both classification schemes. Major elements

and trace elements are plotted against K_2O to arrange the samples from least altered to most altered, as K_2O increases with increasing alteration. This allows for any trends/differences in the geochemistry to be compared to alteration level to determine if the trend/difference is due to alteration level rather than age group or vein type.

Overall, there are no significant major element trends or differences between samples of different age groups (Figure 4.45). Na_2O displays an apparent negative trend, however this trend is likely correlated to alteration level rather than age groups, as an increase in alteration results in a depletion in Na_2O . Group “Protolith/2640 Ma” is sample 622 which is primarily composed of vein material and plots higher than all other samples on the SiO_2 plot (Figure 4.45). All other samples are composed primarily of the altered host rock rather than the vein material. Therefore, the differences in major element chemistry are likely due this difference in sample type.

One sample in the 2700/2670 Ma group (sample 261) plots away from the general data clusters for $Fe_2O_3(T)$, MgO , CaO , Na_2O , and P_2O_5 (Figure 4.45). However, the other sample in this age group (sample 264) does not follow the same pattern, suggesting these major element differences may not be related to the age group. Sample 261 is the only sample that is associated with a V3 vein, which may be the reason for these differences in major element concentrations (Figure 4.46).

The age group sample classification shows similar chondrite normalized REE trends (Figure 4.47) between all groups, with the exception of sample 261 (in the 2700/2670 Ma group) and 622 (protolith/2640 Ma). Sample 261 plots higher than all other samples and 622 plots lower than all other samples. These trends are also reflected in the vein type classification plot (Figure 4.48) and are likely due to reasons discussed above regarding differences in major element patterns.

One sample in the vein type classification has a different REE trend to the rest, sample 625. This sample shows an increase in the heavy REE compared to the rest of the samples (Figure 4.48), and it shows an enrichment in $\text{Fe}_2\text{O}_3(\text{T})$ and TiO_2 (Figure 4.46) however it does not differ from other strongly altered samples in terms of its mineralogy or texture.

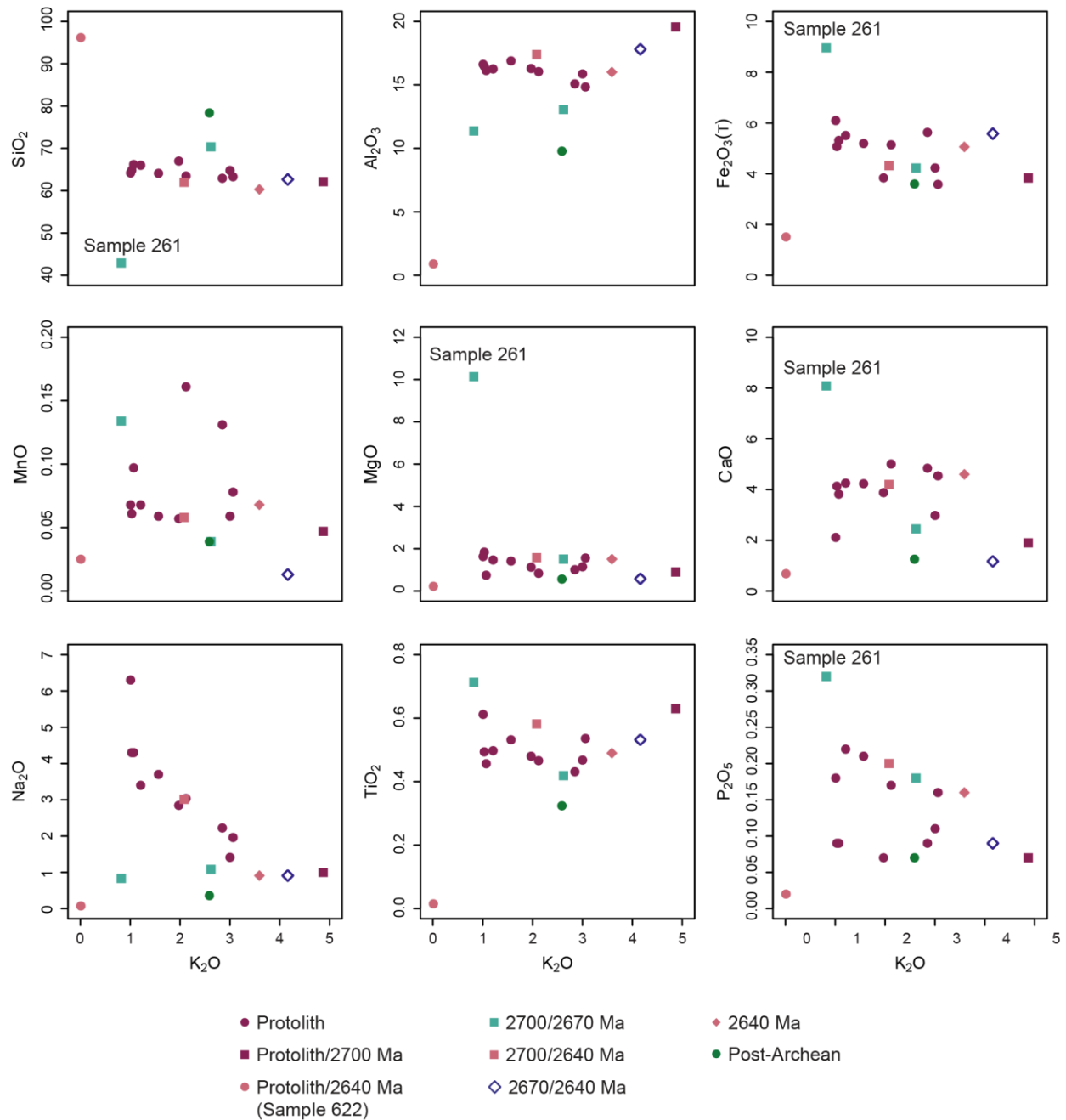


Figure 4.45: Major element oxides (wt %) vs K_2O (wt %) for the age set classification. All 18 dacite samples discussed in Section 4.2 are included.

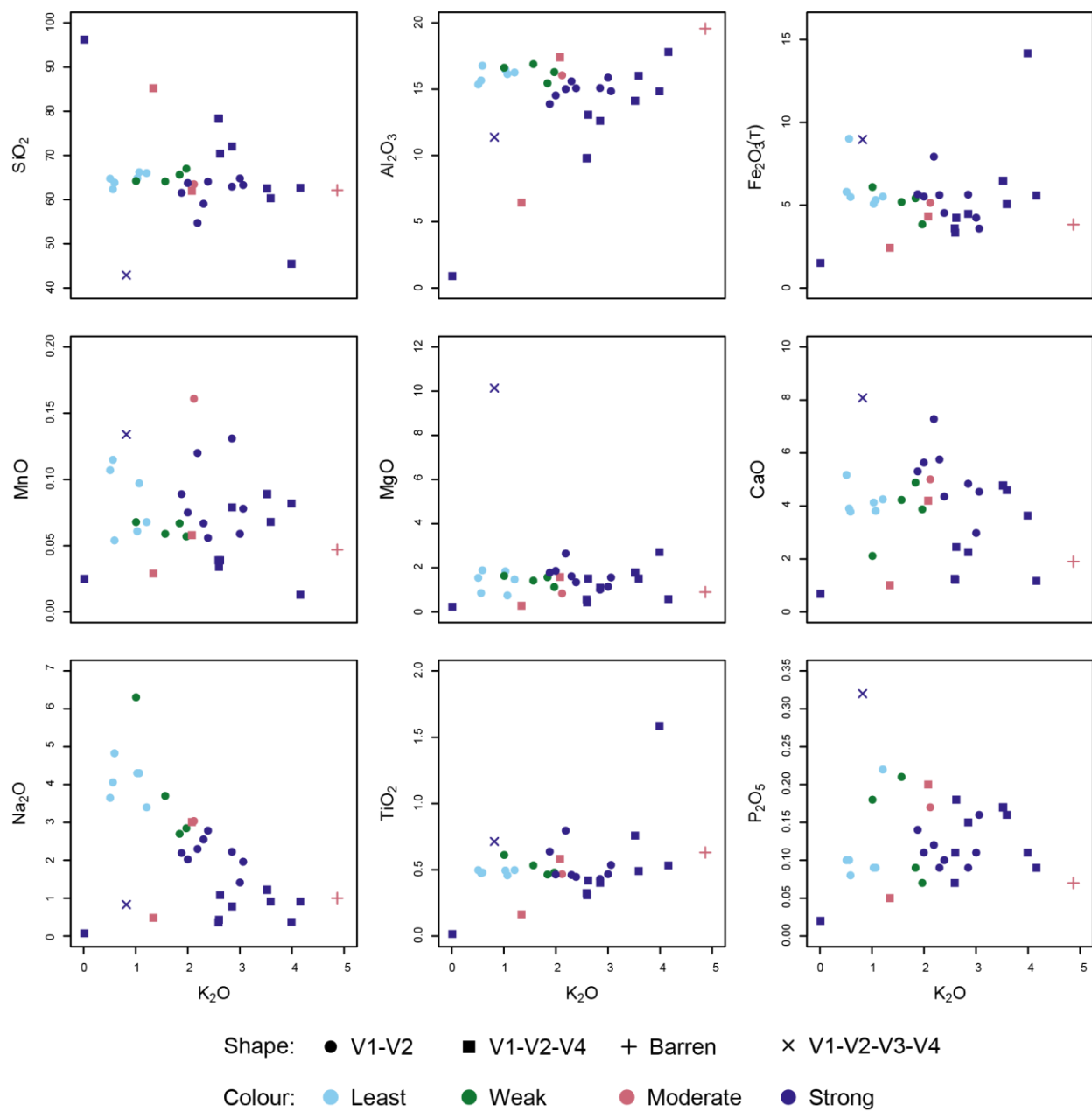


Figure 4.46: Major element oxides (wt %) vs K_2O (wt %) for the vein type classification. All 32 dacite samples are included.

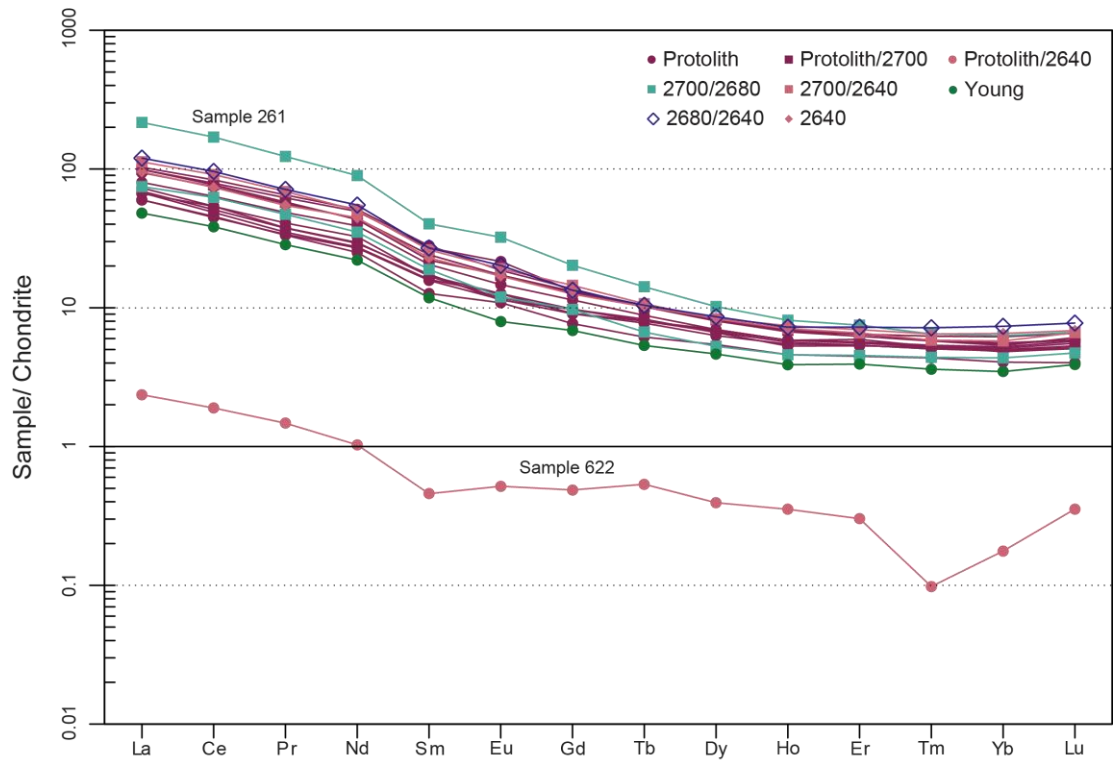


Figure 4.47: Chondrite normalized rare earth element diagram for samples classified by age group. Chondrite normalization values from Sun and McDonough (1989).

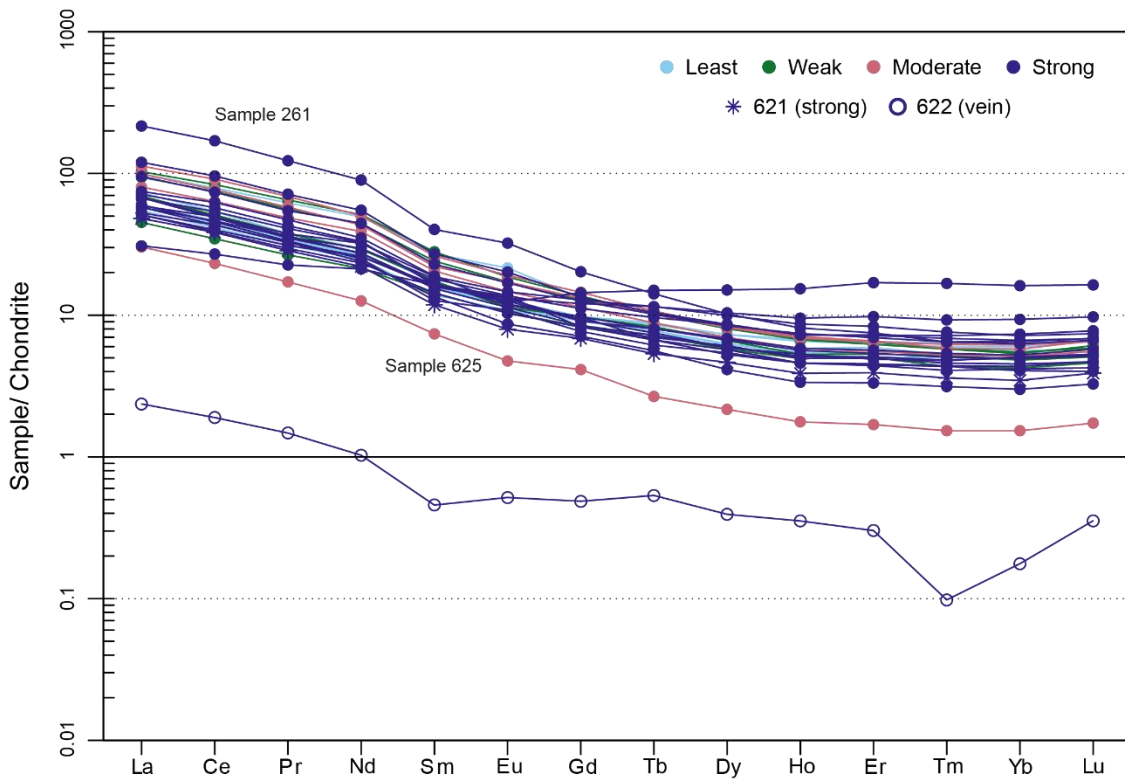


Figure 4.48: Chondrite normalized rare earth element diagram for samples classified by vein type. Chondrite normalization values from Sun and McDonough (1989).

4.3.2 Oxygen-Hydrogen Isotopes

Samples 601 – 625 have $\delta^{18}\text{O}$ values that vary between 7.8 ‰ to 11.5 ‰, which is within the typical values for orogenic gold deposits (Goldfarb and Groves, 2015), and the $\delta^2\text{H}$ values range between -87 ‰ to -59 ‰. Samples plot within both the magmatic and metamorphic zones on a fluid source discrimination plot (modified after Sheppard, 1986), and five plot outside these regions (Figure 4.49). Most least altered and weakly altered samples plot within the magmatic region or below, and the strongly altered samples plot across both the magmatic and metamorphic regions (Figure 4.49). Sample 621, containing post-Archean zircon dates, plots in a similar region to the other strongly altered samples.

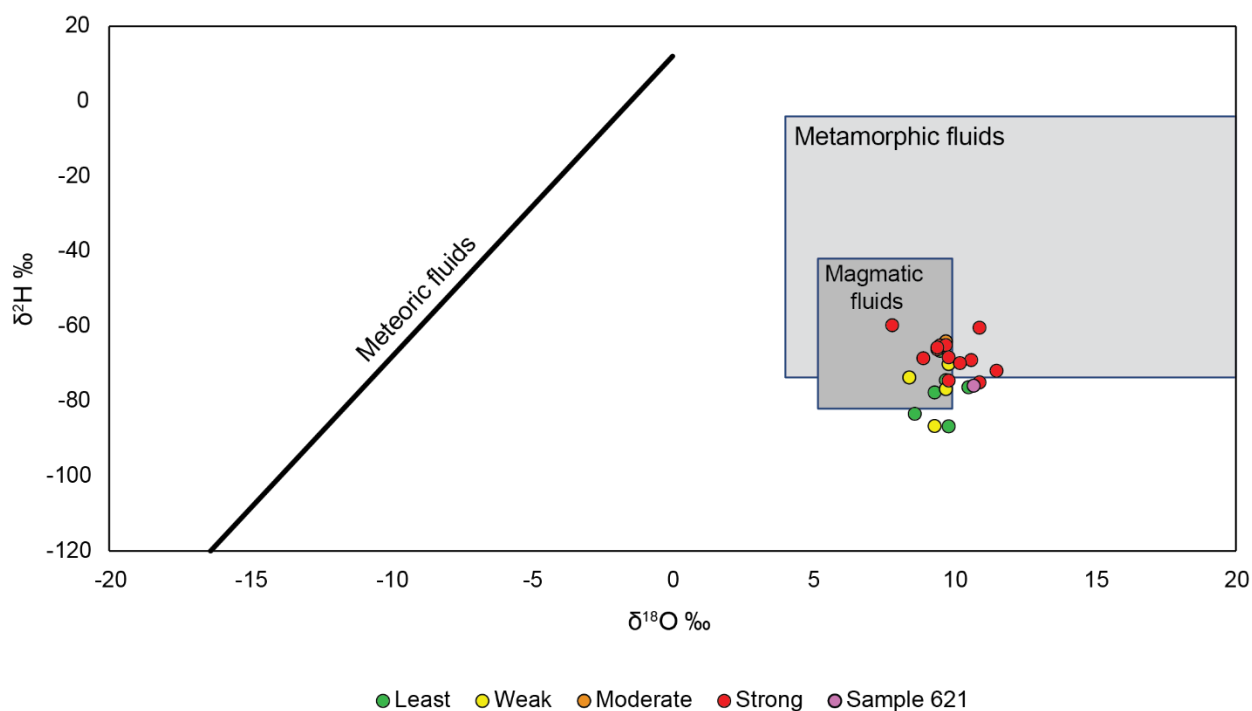


Figure 4.49: $\delta^2\text{H}$ vs $\delta^{18}\text{O}$ fluid source discrimination plot, modified after Sheppard (1986).

4.3.3 Sulfur Isotopes

Sixteen samples were analyzed for $\delta^{34}\text{S}$ isotopes. Twelve samples are strongly altered, two are moderately altered and two are weakly altered, all by V1-V2 veining and six are also associated with V4 veining. Figure 4.50 compares the $\delta^{34}\text{S}$ isotopes samples of this study to

those of Ciufo (2019), as well as to sample 621 and TY128 (sample TY128 from Ciufo, 2019), both of which are strongly altered dacite samples associated with auriferous V1-V2 veining and contain zircons with post-Archean dates. Samples from Ciufo (2019) are moderately to strongly altered dacitic or gabbroic samples altered by V1-V2 veining (see Appendix C for table of values and samples included).

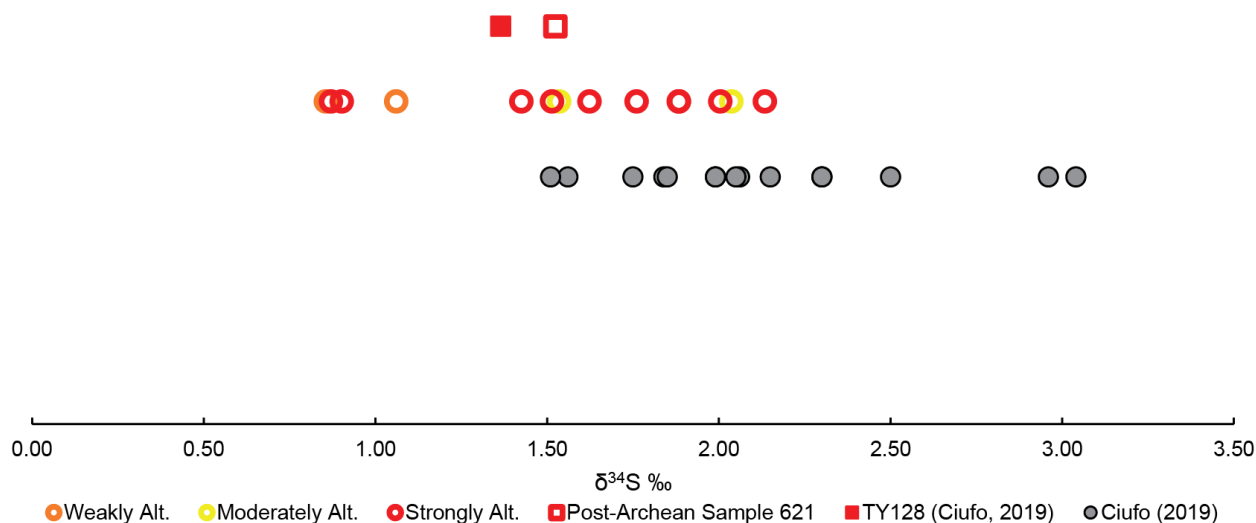


Figure 4.50: $\delta^{34}\text{S}$ isotopes for 15 samples collected in this study compared to $\delta^{34}\text{S}$ isotopes of Ciufo (2019) (grey circles), to sample 621 (empty red square), and to TY128 (Ciufo (2019) sample containing Proterozoic zircons, solid red square).

4.3.4 Zircon Trace Element Concentrations

Selected zircons were analyzed for trace elements after U/Pb isotope analysis was completed in order to target young zircons and protolith-aged zircons. All post-Archean dated grains, a suite of protolith-aged grains (across samples 621, 622, and 616), selected carbonatite grains (from both Groups 1 and 2), and a suite of sample 622 Group 2 (~2633 Ma; part of youngest Archean grouping) were analyzed.

Of the nine trace elements analyzed (Section 3.3.2), only six trace elements and the heavy REEs (Tb to Lu) had concentrations above the detection limit (see Section 3.3.2 for trace element QA/QC).

Zircons from Group 2 of sample 628 (carbonatite sample) differ from the protolith-aged zircons in their concentrations of Y, Nb, Hf, and Pb (Figure 4.51). Sample 628 Group 2 zircons show a general enrichment in Y, Nb, and Pb and a depletion in Hf. Sample 622 Group 2 zircons, which have similar U/Pb ages to sample 628, show similar enrichment patterns for Y and Nb, and also are enriched in U compared to protolith-aged grains. Sample 628 Group 2 and sample 622 Group 2 zircons show similar HREE concentrations and patterns to the protolith-aged zircons, with a few grains of 628 Group 2 and 622 Group 2 showing higher concentrations of HREE than protolith-aged zircons, and one Sample 628 Group 2 zircon showing lower concentrations than all other zircon grains (Figure 4.52).

Sample 628-Group 1 zircons display different trace element concentrations to the 628-Group 2 zircons and similar trace element concentrations to the protolith-aged dacite zircons (Figure 4.53). Group 1 zircons do not show any enrichment in Y, Nb, Pb, or Th when compared to the protolith-aged zircons, unlike the 628-Group 2 zircons. In particular, the Hf concentrations of the 628-Group 1 zircons fall within the same range of values as those of the protolith-aged zircons, while the 628-Group 2 zircons have significantly lower Hf concentrations than both 628-Group 1 and the protolith-aged grains.

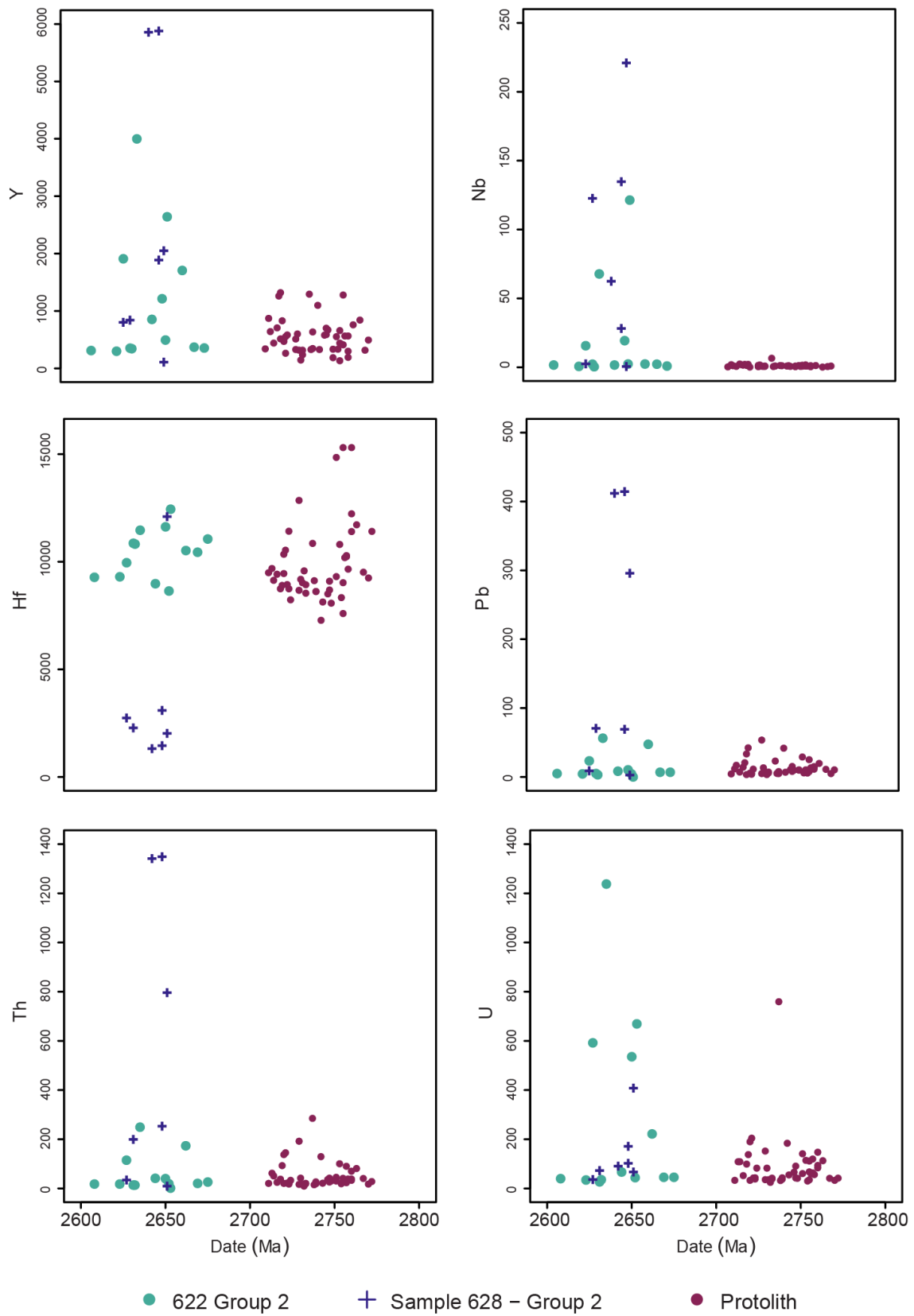


Figure 4.51: Zircon trace element concentrations (in ppm) of Y, Nb, Hf, Pb, Th, and U vs age of the zircon grain (in Ma). Protolith-aged zircons, sample 622 Group 2 zircons, and sample 628 (carbonatite) group 2 zircons are included.

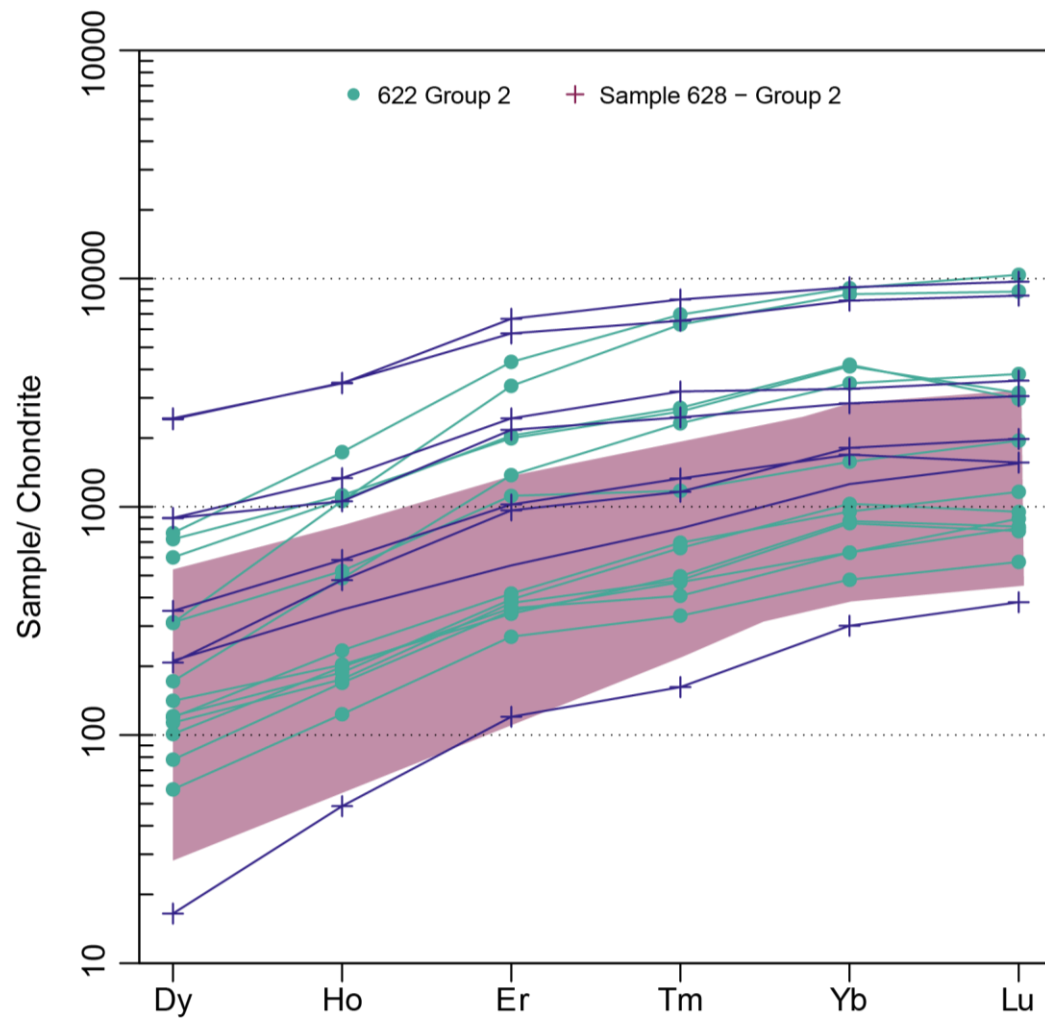


Figure 4.52: HREE chondrite-normalized plot of protolith-aged zircons (red field), sample 622 Group 2 (teal circles) and sample 628 Group 2 (blue crosses) zircons. Chondrite normalization values of Sun and McDonough (1989).

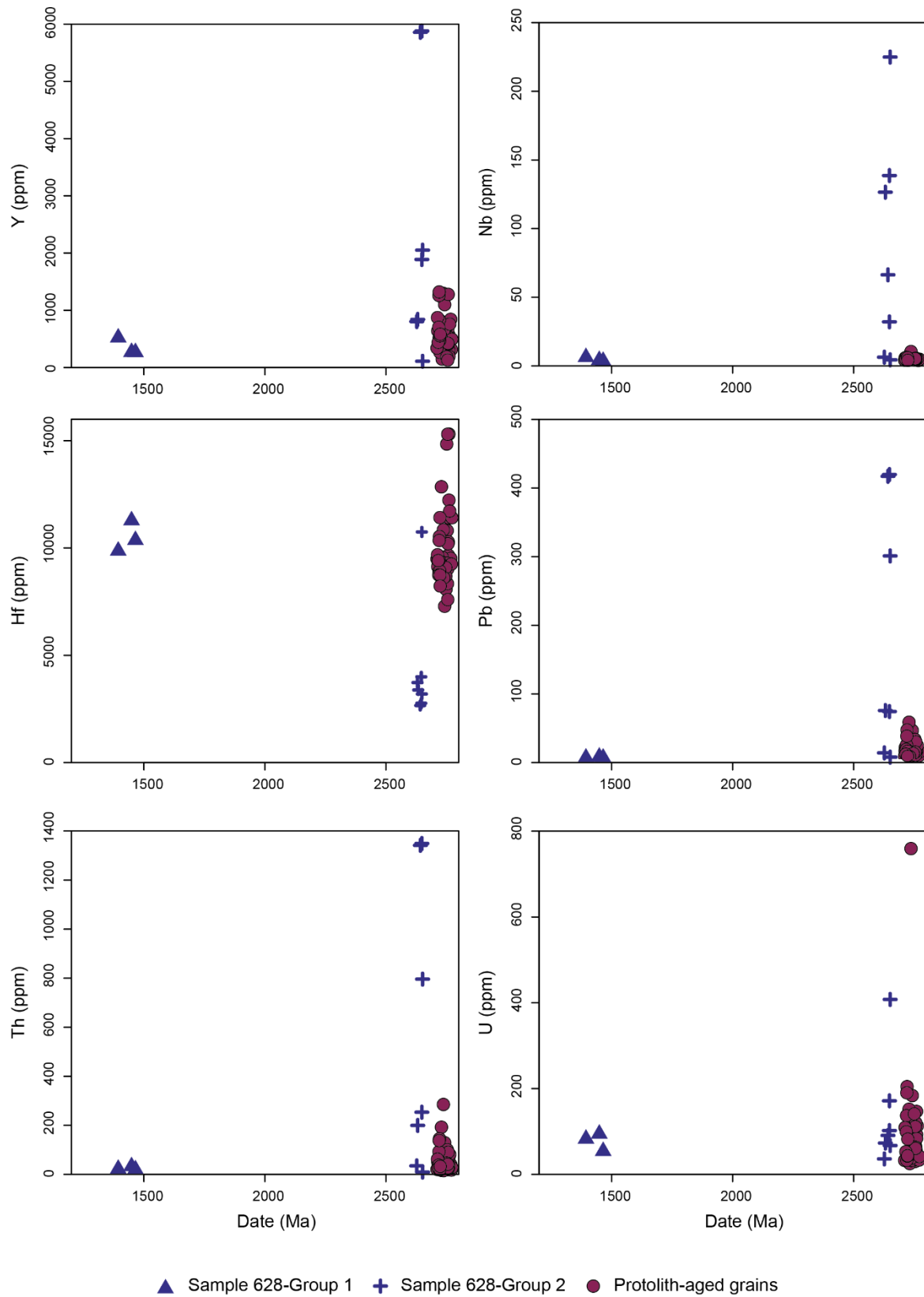


Figure 4.53: Trace element concentrations of sample 628 Groups 1 and 2, and a selection of protolith-aged grains.

Hf and Pb concentrations of the post-Archean zircons are generally similar to the protolith zircons (Figure 4.54, A and C). U concentrations are generally higher in the post-Archean zircons than the protolith zircons (Figure 4.54 and Figure 4.55). A moderate enrichment of Nb and Y in the post-Archean zircons compared to the protolith zircons is apparent (Figure 4.54, B and F respectively), as is a slight enrichment in Th (Figure 4.54, D) in the post-Archean zircons.

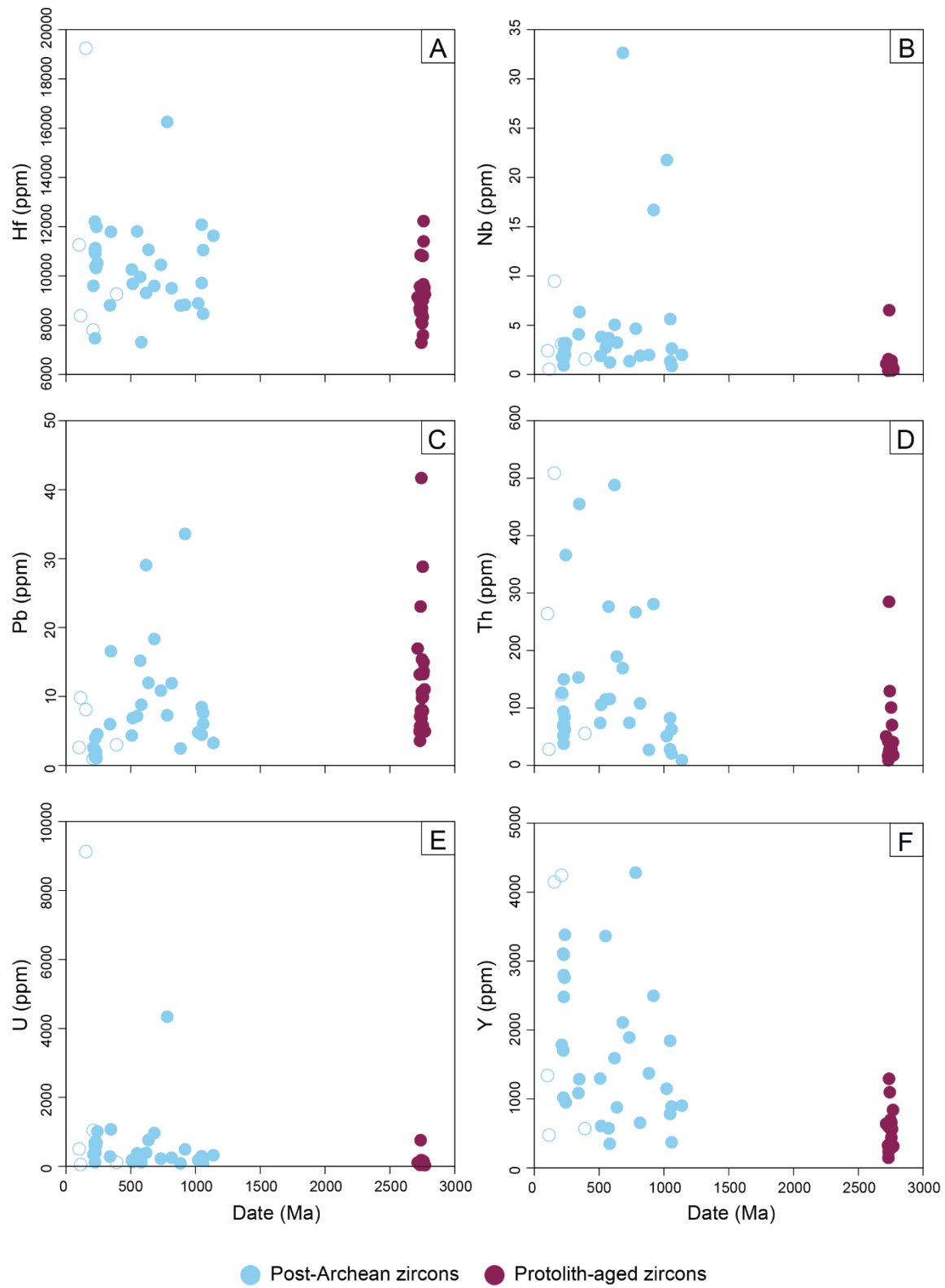


Figure 4.54: Trace element concentrations (in ppm) of individual zircon grains vs their dates. Blue circles are all post-Archean grains from sample 621, and red circles are protolith-aged grains from sample 621. Protolith-aged zircons are $^{207}\text{Pb}/^{206}\text{Pb}$ dates and post-Archean grains are $^{238}\text{U}/^{206}\text{Pb}$ dates. Six trace elements are plotted: a) Y; b) Nb; c) Hf; d) ^{208}Pb ; e) Th; and f) ^{238}U .

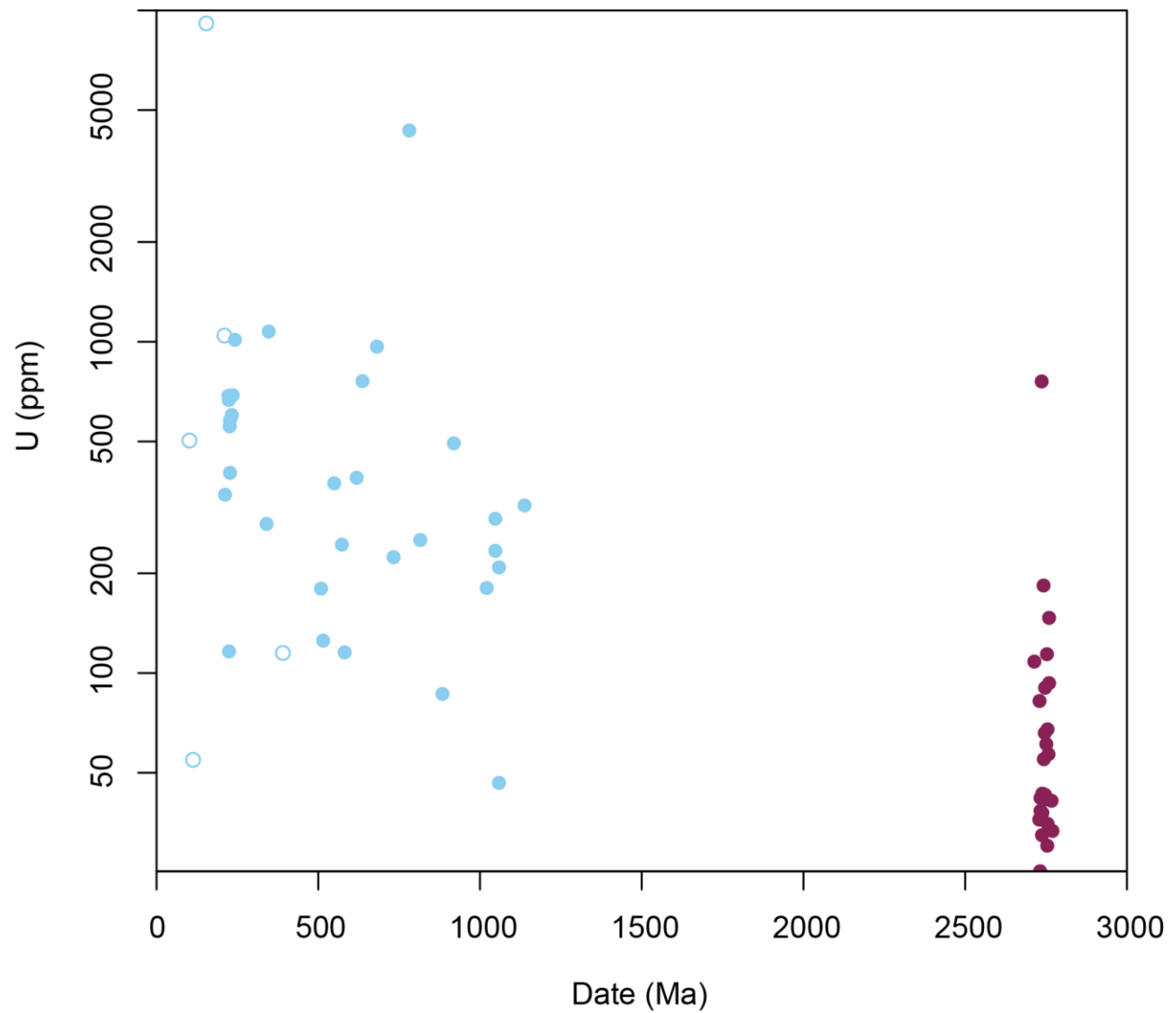


Figure 4.55: U (ppm) vs zircon dates in post-Archean zircon grains (blue) and protolith-aged grains (red). U (ppm) axis is logarithmic to better display the spread in concentrations.

Heavy REE in zircon are plotted on Figure 4.56. In general, 621 post-Archean zircons show enrichment in HREEs compared to protolith values, however there is also overlap between the groups.

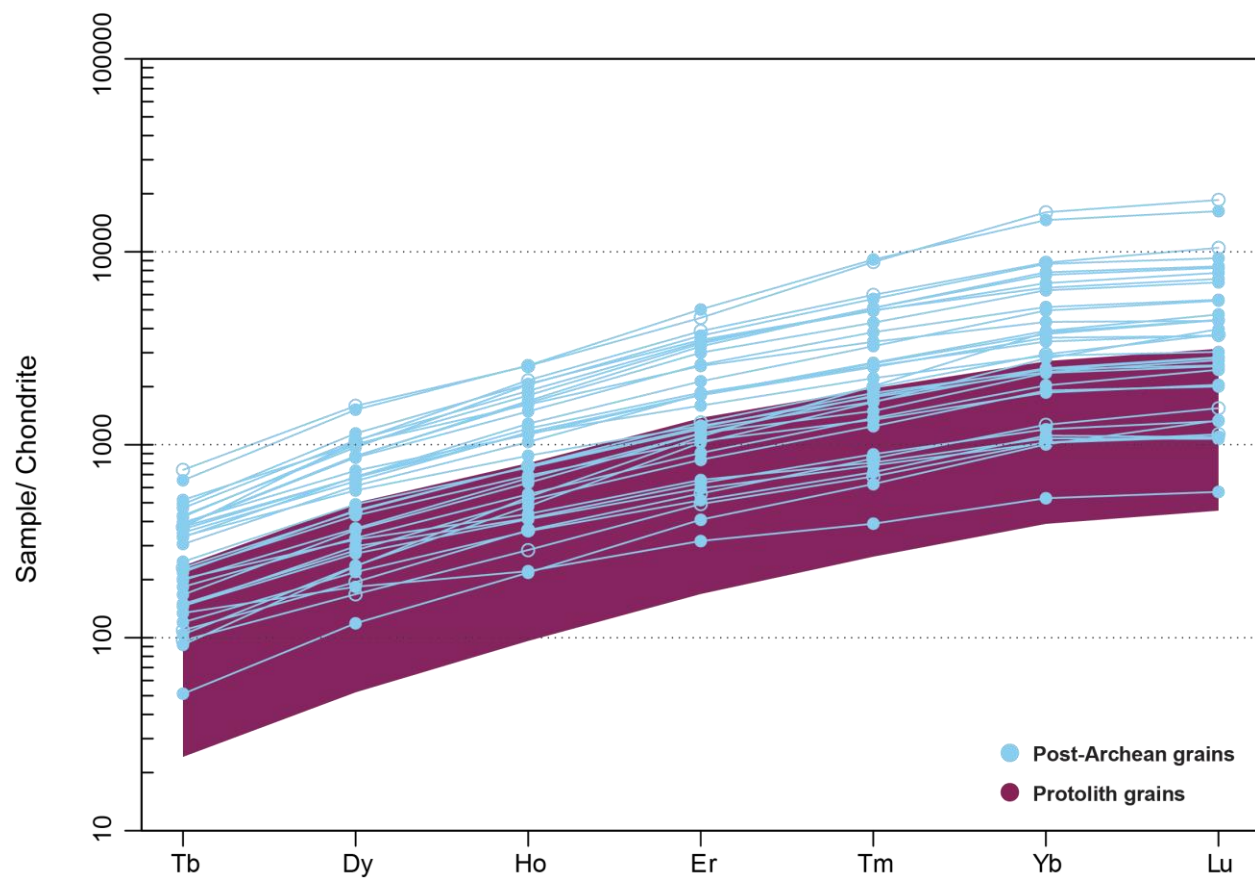


Figure 4.56: HREE plot of all 621 post-Archean zircons (lines and points) compared to 621 protolith zircon HREEs (shaded red area). Empty blue circles are grains where laser analysis was slightly off edge of the grain (as noted in Section 4.2.4.2), filled blue circles are all other post-Archean grains. Chondrite normalization values from Sun and McDonough (1989).

5.0 Discussion

Evaluating the geological significance of young zircon dates and their potential link to gold mineralization at Island Gold requires integrating the various datasets provided in this thesis, including stable and radiogenic isotope analyses and zircon trace element analyses. I focus on sample 621, which contains the majority of young zircon dates and shows no differences in mineralogy or texture compared to other strongly altered dacite samples, at both the thin section and hand sample scales.

5.1 O-H and S Isotopes

Stable isotopes (O, H and S) can be used to infer the nature of fluids that interacted with various rock types assuming that the fluid–rock ratio was high enough. Samples from Island Gold have $\delta^{18}\text{O}$ (VSMOW) that vary from 7.8 ‰ to 11.5 ‰, and $\delta^2\text{H}$ values range between -87 ‰ to -59 ‰ (Section 4.3.2). Higher values of $\delta^2\text{H}$ indicate a larger proportion of ^2H , whereas lower $\delta^2\text{H}$ values indicate a larger proportion of ^1H . Similarly, higher $\delta^{18}\text{O}$ values indicate a higher proportion of ^{18}O while lower $\delta^{18}\text{O}$ values indicate a larger proportion of ^{16}O (Hoefs, 2021). $\delta^2\text{H}$ values for different geologic reservoirs (igneous and metamorphic rocks, sedimentary rocks, etc.) have significant overlap; $\delta^{18}\text{O}$ values for metamorphic, igneous, and sedimentary reservoirs display moderate overlap ($\sim 0\text{--}20\text{‰}$, $-5\text{--}15\text{‰}$, and $\sim 10\text{--}40\text{‰}$ respectively) (Hoefs, 2021).

In general, $\delta^2\text{H}$ values are fractionated through several processes, including fractionation between water phases (solid/liquid/gas) and water-mineral phases. Meteoric water values range from very high (up to 50‰) to very low ($\sim -150\text{‰}$ to -350‰), while igneous and metamorphic fluids are typically between $\sim -50\text{‰}$ to -120‰ (Hoefs, 2021). Water-mineral fractionation is complex, being influenced by a number of factors including temperature and pressure conditions

and mineralogy (both crystallography and mineral chemistry). $\delta^{18}\text{O}$ values for rocks are also influenced by their mineralogy; different minerals have different tendencies to preferentially incorporate ^{18}O over ^{16}O (Hoefs, 2021).

The $\delta^{18}\text{O}$ values of rocks that host Precambrian orogenic gold deposits are generally consistent worldwide and are commonly between +6‰ and +11‰ (Goldfarb and Groves, 2015), and values from Island Gold fall within this range. However, hydrogen isotope ratios vary considerably between deposits due to a number of factors, such as post-mineralization fluid-rock interaction during uplift, and measurement of structurally bound hydrogen isotopes in minerals during analysis (Goldfarb and Groves, 2015). $\delta^2\text{H}$ of alteration minerals associated with gold mineralization often range between -20 ‰ and -80 ‰. These factors often indicate that there is a significant meteoric water component to the ore fluid, however this may be unrealistic given the depth at which orogenic gold deposits form (Goldfarb and Groves, 2015).

Using O and H isotope ratios together, most samples analysed in this thesis fall within the magmatic to metamorphic fluid source region, and six fall just below these regions (Figure 4.49). This spread in the data potentially indicates a mixed fluid source, however due to the number of post-mineralization factors that can impact oxygen-hydrogen isotopes, it is important to interpret these results with caution. The O-H isotope analyses were conducted on whole rock samples rather than V1-V2 vein separates, and so include structurally bound hydrogen isotopes of the host-rock minerals and H from fluid inclusions. Considering these factors as well as the potentially ‘mixed’ source, it is not possible to elucidate the specific source(s) of fluids that formed V1–V2 veins and caused associated gold mineralization. However, and most importantly, these data suggest that there is no difference between sample 621—containing post-Archean zircon dates—and the rest of the strongly altered samples in terms of the O-H isotope

compositions. This suggests that the late fluid activity did not impact the O-H isotope signature of the altered host rock.

Sixteen samples were analysed for $\delta^{34}\text{S}$ isotopes. Twelve samples plot in the same range as the samples from Ciufo (2019). Four of the samples from this study plot below the majority of values, between 0.86‰ and 1.06‰. These four samples are all altered by V1-V2 veining, have similar mineral assemblages and microstructures to the other samples, and those with age data are protolith-aged. As such, these samples are considered to be an addition to the range of $\delta^{34}\text{S}$ values that accompany V1-V2 veining, rather than recording a different fluid event. Samples 621 and TY128 (both of which contain post-Archean zircon dates) plot with the majority of samples, within the same $\delta^{34}\text{S}$ isotope range as presented in Ciufo (2019). Again, this suggests that any post-Archean fluid activity associated with sample 621 and TY128—the samples with young zircon dates—did not impact the $\delta^{34}\text{S}$ isotopes of the strongly altered host rock.

5.2 Geochronology

This thesis employed a LA-ICP-MS analysis technique that used unprecedented small spot sizes (12µm) that were necessary to target the very narrow rims on protolith zircon. This necessity introduces several sources of error to the isotope data that must be taken into consideration before interpreting any geochronological results. These include downhole fractionation (laser-induced U/Pb fractionation), small laser spot sizes, and the matrix-matched suitability of the primary standard.

Downhole fractionation (DHF) is a source of error for all LA-ICP-MS analyses at any spot size. DHF is a change in signal intensity of different elements as the ablation pit deepens during analysis. All signal intensities decrease with increasing depth of the ablation pit; however, the signal of more refractory elements will decrease faster than less refractory elements (Paton et

al., 2010). In the case of U-Pb isotope analyses, U is more refractory than Pb, therefore the U isotope signal will decrease at a faster rate than the Pb isotope signals as analysis progresses. This results in a steadily increasing Pb/U ratio from the beginning to the end of the ablation, which will translate to a steady change in calculated Pb/U dates. This creates different dates at different points in the time-resolved analysis that do not represent real geological information. This also creates problems when taking an average isotope ratio of the entire ablation time, as is general standard practice in data processing software (Chang et al., 2006; Paton et al., 2010). Averaging an analysis impacted by DHF will result in an isotope ratio that is inaccurate to the true Pb/U ratio of the sample. DHF is corrected for in the data reduction of the raw LA-ICP-MS signal data to flatten the ablation signals to obtain a consistent Pb/U ratio; for an in-depth discussion of the DHF correction in Iolite, see Paton et al., 2010.

There are two important aspects of DHF to note for the data in this thesis. As discussed above, DHF impacts U signals, therefore all Pb/U ratios in this thesis were influenced by DHF and were corrected. Different zircon grains from the same sample will also show variable DHF and the causes of this are not always clear. A smaller aspect ratio (diameter to depth) of the ablation pit will result in strong DHF effects (Horn et al., 2000; Košler and Sylvester, 2003). So, DHF is more pronounced when using small spot sizes for typical analysis time lengths (~30s), as was used for this thesis (12 µm). This increased DHF accounts for some of the horizontal spread in the analyses along concordia for all samples. However, signals of Pb isotopes (^{206}Pb , ^{207}Pb , and ^{208}Pb) are expected to behave the same with increasing analysis time/ablation pit depth (e.g. no laser-induced fractionation of Pb). In other words, there is no DHF of Pb isotopes from each other and the ratios do not change during the analysis.

Small spot sizes have been used in previous studies with some accuracy and precision on LA-ICP-MS systems (Mukherjee et al., 2019), however many of those studies used single-collector systems at high fluence (6 – 10 J) to counter-act the decrease in isotope signal due to the decrease in ablated material. Studies that have used a low fluence (1 – 3 J) with small spot sizes on single collector systems obtained results with lower precision than those that used higher fluence (Mukherjee et al., 2019). This thesis employed a multi-collector system, low fluence, highly sensitive ion counters for Pb isotope detection, and a Faraday detector for U isotopes. Low fluence values were necessary to allow use of the sensitive ion counters, however this created a negative trade-off with the U isotope detection as the less sensitive Faraday detector resulted in stronger downhole fractionation due to low U signal detection. This does not have an impact on the $^{207}\text{Pb}/^{206}\text{Pb}$ ratios; however, it does impact the spread of dates on a Terra-Wasserburg concordia diagram and the assessment of concordance.

The uncertainties for the data collected in this thesis are higher than uncertainties calculated in other studies at small (~20 μm) spots, both in the discordance of each analysis and the imprecision of the secondary standard dates. A possible reason for this increased imprecision is the Archean age of the zircon secondary standards and the samples, and the low fluence used during analysis. Studies have shown that increased radiation damage to a zircon crystal can result in increased downhole fractionation even at larger ablation spot sizes (Mukherjee et al., 2019). So, the combination of high metamictization with a small ablation spot size may result in stronger DHF and consequently stronger discordance and less precision of the collected and calculated isotope ratios. Another compounding factor may be the primary standard used in the data reduction. Zircon natural standard 91500 was chosen as the primary standard due to its homogeneity, consistent ablation signals throughout all analysis sessions and use as an

international cross-laboratory reference material. However, zircon 91500 is Proterozoic in age (~1065 Ma) with relatively low concentrations of U (and Pb) whereas the secondary standards and study samples are Archean-aged (and are more heterogeneous in composition). Therefore, zircon 91500 is not an ideal matrix-matched standard for the samples which may account for some of the uncertainties of the presented data. It is important to note that it is likely a better matrix-match for the post-Archean aged zircons, which are the primary focus of this thesis.

Despite the low precision and moderate to high discordance of many analyses, there are apparent post-Archean zircon dates within this Archean deposit. It is not possible to determine precise ages for these populations of dates due to the low precision of the analyses, and the low quantity of post-Archean zircons, however their presence is not considered to be due to analytical artifacts. Therefore, with the caveats listed above for interpreting precise dates from each analysis, I consider the data fit for the purpose of evaluating if there are resolvable post-Archean ages preserved in the zircon grains.

There is a large group of analyses that correspond to the suggested protolith age of Ciufu (2019) at ~2738 Ma, however they display a wide overall spread and likely represent a poorly constrained protolith population of zircons. There is also evidence of some activity within the deposit at c. 2670 Ma and c. 2640 Ma, after protolith emplacement. There is known geological activity in the area during both of these time frames (widespread felsic plutonism and deformation c. 2670 Ma (Jellicoe et al., 2022), and carbonatite dyke emplacement c. 2640 Ma [this thesis, Sections 4.2.3.2 and 5.2.2.2]). These populations may represent real geological events, but we cannot rule out a potentially significant component of analytical uncertainty. Nevertheless, the coincidence between these regional ages and the dates retrieved from zircon from Island Gold suggest that there is some imprint of these regional events in the zircon record.

A typical approach to calculate crystallization ages of a rock is combining several individual analyses into a weighted mean age (Horstwood et al., 2016). Several statistical measures are then used to evaluate if the dispersion of the data is due to geological or analytical factors (e.g. Spencer et al., 2017). Given the imprecise nature of our analyses, this approach is not used because the dispersion is high and is caused by analytical factors. For example, even for our secondary reference materials that have well-constrained ages, weighted mean calculations produce MSWD values >1 for all groups (see Appendix A: U-Pb Secondary standard concordia diagrams); analytical uncertainties would need to be inflated by up to 2% to obtain MSWD values at ~ 1 or below. This is a significant artificial increase in the analytical uncertainties and is therefore not applied to the data in this thesis. Furthermore, post-Archean zircon have too few analyses that produce reasonable pooled post-Archean dates. There is no *a priori* reason why zircon should completely re-equilibrate due to a fluid or thermal event and grouping dates together that record these processes is not consistent with the underlying statistical assumptions of a weighted mean calculation (i.e. the duration of the geological process may be longer than the analytical resolution of the data). With all of the above uncertainties and caveats in mind, the following sections of this discussion are interpretations of the geological significance of the dates discovered in this thesis.

5.2.1 Mechanisms of Zircon Recrystallization and Re-setting

There are two primary mechanisms that are proposed to recrystallize zircon and reset the U-Pb isotopic clock: coupled dissolution-reprecipitation, and diffusion reaction processes. These mechanisms result in different physical changes to the zircon crystal which can be detected using CL imaging, and differences in the trace element characteristics of the impacted zircon domains.

Dissolution-reprecipitation is a coupled process by which zircon domains, typically rims, are dissolved in the presence of a fluid or melt (Geisler et al., 2007). New zircon is then reprecipitated on the partially dissolved zircon, which often includes micro-inclusions of trace element-rich phases, such as thorite or xenotime. These reprecipitated domains often have lower trace element concentrations compared to the original composition, and a completely reset U-Pb isotope system (Geisler et al., 2007; Grant et al., 2009). This process results in inclusion-rich domains that are detectable in CL imaging and appear as a “bubbly” texture. The zircon cores often have embayed boundaries with the newly precipitated domains (Harley et al., 2007).

Diffusion reaction processes can occur in lower temperature conditions (down to $<200^{\circ}\text{C}$) and require the presence of fluids to facilitate the leaching of chemical species from metamict zircon domains. Recrystallization of these domains can also occur in the presence of fluids, at temperatures of 200°C or higher (Geisler et al., 2007, 2003). Diffusion and recrystallization can occur as rims, along fractures, and has been shown to impact complete zircon grains (Grant et al., 2009). Leaching of Pb results in re-setting the U-Pb clock and can result in partial or complete Pb loss. This often is accompanied by an increase in non-formula elements (such as Ca or Fe) and other trace elements dependent on the chemical composition of the leaching fluid, and a decrease in U and Th (Geisler et al., 2007, 2002). Recrystallization of the affected domains results in structural recovery, and therefore these zones are brighter in CL imaging (Grant et al., 2009).

The post-Archean zircons from Island Gold display internal features consistent with both dissolution-reprecipitation and diffusion reaction processes. Post-Archean zircon are brighter in CL than the Archean-aged zircons in the same samples, suggesting structural recovery has occurred as with diffusion-reaction processes, however they do not contain high amounts of non-

formula elements or show a depletion in U as would be expected from previous experimental studies (Appendix E); in fact, the bright, young domains are enriched in U compared to the Archean-aged zircons. However, the lack of micro-meter sized inclusions (“bubbly” texture) and embayed boundaries (features of dissolution-reprecipitation) make diffusion-reaction processes the more likely mechanism by which these young zircon domains developed.

5.2.2 Younger Archean Date Groups

With the caveats about the zircon U–Pb data in mind, the following two sections discuss the potential geological implications of these date groups.

5.2.2.1 ~2670 Ma Dates and ~2700 Dates

This group of dates corresponds to the timing of greenschist metamorphism of the Island Gold mine and surrounding region and therefore may reflect the timing of this event. Greenschist facies metamorphism does not typically cause Pb-loss and re-setting of the U-Pb clock in zircons, however the presence of fluids can facilitate Pb-loss when the zircons are strongly metamict (Geisler et al., 2002). The creation of strongly metamict zircons requires high concentrations of U and sufficient time for the U radioactive decay to damage the zircon crystal lattice (Geisler et al., 2002). Trace element analyses were not conducted on zircons of this age group, however semi-quantitative U concentrations from the U-Pb isotope analyses (Appendix B) can be examined. Values are relatively low (typically between 40ppm – 100ppm), similar to values found in the primary zircon standard 91500 (80ppm).

This age group is only ~70 million years younger than protolith-aged zircons. Given the relatively short time between zircon formation (protolith-age of ~2737 Ma) and this age group, and the low U concentrations, it is unclear if these zircons contained sufficient U to cause pervasive and substantial radiation damage to the crystal lattice. This would be apparent in the

CL images, which do not show the dark CL response expected for metamict zircons (Figure 4.27, Figure 4.28, Figure 4.29). It is more likely that this group of analyses has no geological significance and is instead a product of the analytical sources of error described in Section 5.2, or could represent minor Pb loss. Similarly, the group of dates around 2700 Ma are potentially also caused by these analytical errors, for the same reasons discussed above (short time span, U concentrations).

5.2.2.2 ~2640 Ma Group

Sample 628 (carbonatite dyke) produced a group of dates between ~2663 Ma to ~2628 Ma (Group 2) with an average of ~2645 Ma, as well as three zircons with dates of ~1418 Ma, ~1408 Ma, and ~1362 Ma (Group 1). These 628-Group 1 Proterozoic grains display different CL patterns to the 628-Group 2 ~2663 – 2628 Ma group (Figure 4.34) and are therefore considered to be separate and will be discussed later in this section.

The 2663–2628 Ma group of zircons from sample 628 are very mottled in CL, with variable CL intensity within individual grains. These zircons are interpreted to be primary zircon from carbonatite crystallization rather than zircons scavenged from the host rock during dyke emplacement, due to their high levels of Nb, U, and their low levels of Hf, which are in contrast to zircon trace element concentrations in those in felsic to intermediate igneous rocks in the region (Figure 4.34). These zircon dates therefore represent the crystallization age of the carbonatite dyke (Section 4.2.3.2) and gives an average age of ~2646 Ma.

Sample 622 produced zircon dates between ~2682 – 2594 Ma (average ~2630 Ma) (622-Group 2) and a group with dates comparable to the inferred protolith-age of the host rock (622-Group 1). Sample 622-Group 2 zircons are of a similar date range to the carbonatite dyke (628

Group 2) and display similar trace element enrichment as the sample 628 Group 2 zircons (Figure 4.51).

Carbonatite intrusions are volatile-rich, and often cause alteration to the surrounding host rock during cooling and crystallization, termed “fentitization”. These alteration fluids are typically enriched in REEs (including Y) and high field strength elements, including Nb (Elliott et al., 2018; Sokół et al., 2021). Fentitization can occur as a pervasive phenomenon, creating an alteration halo around the carbonatite intrusion, or can occur as fracture-controlled fluid flow. Fentizing fluids that move along fracture pathways can travel greater distances while retaining their alkali and volatile-enriched chemistry, as interaction with the wall rock is more limited during efficient fluid transport (Elliott et al., 2018).

The enrichment of carbonatite-associated fluids in Nb and Y, among other elements, and the potential for these fluids to travel long distances, allows for the possibility of fluid interaction between the carbonatite dyke and the Island Gold deposit. In addition, small carbonatite dykes have been found at depth within the Island Gold deposit, both during underground mapping and within drill core, further increasing the possibility of fluid infiltration from carbonatite activity. Both the 628-Group 2 zircons and the 622-Group 2 zircons were similarly enriched in Nb, Y, and U compared to the protolith-aged zircons. In addition, most of the 628-Group 2 zircons were analysed on rims that were dark grey in CL, in contrast to the lighter grey interiors of the zircons, and the rims often terminated in sharp points. This morphology and CL colouring is in contrast to the 622-Group 1 zircons that produced inferred protolith dates, which were entirely light grey in CL and did not have dark rims or pointed terminations (Figure 4.24).

Sample 263-Group 1 also produced dates between ~2645 – 2628 Ma (average ~2640 Ma), however no trace elements were analysed for this sample. Due to the similarity in zircon

dates, it is possible that this sample was also impacted by carbonatite-associated fluids, however this would need to be tested with further trace element analyses.

Sample 628-Group 1 displays CL imagery that is similar to the CL patterns of the area's felsic-intermediate host rock (oscillatory zoning, consistent light grey CL colour) (Figure 4.34 and figures within Section 0). They also display similar trace element concentrations to the protolith-aged zircon grains (Figure 4.51). However, these zircon grains produced U-Pb dates of ~1418 Ma, ~1408 Ma, and ~1362 Ma, which are not the inferred protolith-age of the dacite host rock. These sample 628-Group 1 zircons are interpreted to be zircons scavenged from the region's country rocks, due to similarities of trace elements, that were incorporated into the carbonatite dyke during emplacement into the Webb Lake Stock. The dates of these zircons indicate that they have been impacted by a young fluid event, possibly the same event that created the post-Archean dates within the dacite of Island Gold (see Section 5.2.3).

5.2.3 Post-Archean dates

There is an array of post-Archean dates from strongly altered samples associated with auriferous V1-V2 veining that range from ~1138 Ma to 105 Ma, and one grain at 1408 Ma. This is a ~1000 Ma spread in dates that show variable concordance. Most analyses are from Sample 621, with one analysis each from sample 602 and sample 622. One other sample, TY128, from Ciufu (2019) also produced post-Archean dates (~1260 – 1170 Ma), several of which were re-analysed in this study and produced similar results (~1408 – 1080 Ma).

Two concordant clusters of dates are present, one between ~1138 Ma – 1021 Ma (comprised of analyses from sample 621 and TY128, 9 analyses total) and another between ~243 Ma - ~224 Ma (6 analyses, all from sample 621). These concordant clusters suggest that there was geological activity occurring within the Island Gold mine at those time periods. The

remainder of the post-Archean analyses create a discordant spread between these two clusters, with only 3 concordant analyses at ~648 Ma, ~563 Ma, and ~347 Ma. These 3 concordant analyses potentially record geological activity, but, considering the limited number of analyses with these dates, these results are not discussed further.

The Superior Province has experienced minimal tectonic activity from 2.6 Ga to the present, with some exceptions, and is considered to have been a stable craton since the Neoarchean. Tectonic activity occurred at the northeastern and northwestern margins of the Superior at 1.9 Ga, and the Grenville orogeny affected the southern margin c. 1.1 - 1.0 Ga (Hynes and Rivers, 2010; Percival, 2007). The interior of the craton experienced the Kapuskasing Uplift event at ~1.9 Ga, the Midcontinent Rift (MCR) (~1115 – 1105 Ma), the Abitibi dyke swarm at ~1140 Ma, and sporadic dyke swarms at various times, such as the Matachewan dyke swarm at ~2.4 Ga and the Nipissing dyke swarm at 2.2 Ga (Ernst and Bleeker, 2010; McDannell et al., 2018).

The MCR and the Abitibi dyke swarm occur at a similar time to this study's cluster of concordant zircon dates between ~1138 Ma – ~1021 Ma. This allows for the possibility that MCR activity is responsible for the presence of these young zircon domains in the Island Gold mine. The MCR was a failed intracratonic rifting event that involved two main pulses of magmatic activity at 1115 – 1105 Ma and 1100 – 1094 Ma, with a pre-cursor magmatic pulse at 1150 – 1130 Ma (Ernst and Bleeker, 2010). The MCR is generally thought to have initiated by a large mantle plume, which resulted in the Keweenawan flood basalts and the associated sub-surface dyke swarms (Ernst and Bleeker, 2010). Some studies suggest that extensive magmatic underplating of the region surrounding the MCR locus (under today's Lake Superior) extended into the eastern and western Superior Province, and the resultant doming of the lithosphere could

extend for up to 650 km away from the centre of MCR magmatic activity (McDannell et al., 2018). In addition, McDannell et al. (2018) suggest that the geologic units in the southern Superior Province were heated to temperatures of $\sim 200^{\circ}\text{C}$ due to this magmatic underplating. The Abitibi dyke swarm (c. 1140 Ma) is considered to be related to MCR activity, and extends from Lake Superior into the Abitibi province, east of Island Gold (Ernst and Bleeker, 2010; Ernst and Buchan, 1993).

It is possible that far-field stresses from the MCR rifting activity re-activated the veins within Island Gold, creating permeability pathways that allowed fluids from the subsurface MCR magmatic activity to infiltrate the deposit. These fluids, in combination with the increased temperatures in the region due to magmatic underplating, would create the necessary conditions for zircon recrystallization through diffusion-reaction processes.

This study examined samples along a gradient of alteration levels, primarily associated with the main auriferous veining of the deposit, V1-V2 veining. Only strongly altered samples, sampled proximal to V1-V2 veins, produced zircons with post-Archean dates. This suggests that the V1-V2 vein set was re-activated, and that the external fluid did not penetrate very far into the surrounding host rock. Further support for limited fluid penetration is the similarity of the stable isotope values (O, H and S) of sample 621 to all other samples across alteration levels (Section 5.1).

Twenty strongly altered samples were analysed (nineteen samples collected in this study, one sample from Ciufu, 2019), and only four samples produced post-Archean zircon dates, two of which produced dates circa 1100 Ma. This scarcity in post-Archean zircon grains may suggest that there are particular structural controls that limit the external fluid flow to specific veins within the mine. Within the samples that produced post-Archean dates, a low number of the

zircons analysed were post-Archean, which may be due to a preservation bias. This may be due to differences in uranium concentration of the zircon grains at their initial crystallization, resulting in different levels of metamictization and susceptibility to fluid-related dissolution and/or recrystallization. Zircon grains that produced post-Archean dates in general contained higher concentrations of uranium than zircon grains that produced inferred protolith dates (see Appendix B: LA-ICP-MS U-Pb Isotope Data, and U-Pb Age Data).

The second concordant cluster of post-Archean dates discovered in this study is between ~223 Ma to ~243 Ma. The significance of this cluster of dates is more enigmatic, as there was minimal geologic activity in the southern Superior Province at this time. Despite the paucity of geologic activity, there was kimberlite emplacement to the west (Lake Ellen, ~200 Ma), to the east (Kirkland Lake, ~150 – 160 Ma), and to the north (Attawapiskat, ~180 Ma) of the Island Gold mine between ~150 Ma to ~200 Ma (Heaman et al., 2004). These kimberlites are associated with the Great Meteor hotspot track that crosses through the Superior Province in a southwest direction from ~180 Ma through ~100 Ma (Heaman et al., 2004). Hotspot activity, and its associated magmatic underplating, may have resulted in a second re-activation event at Island Gold, re-opening the V1-V2 veins and allowing external fluids to infiltrate once again. This could have caused the cluster of dates circa 223 Ma – 243 Ma, as well as the discordant dates between ~1021 Ma and ~102 Ma by incomplete Pb loss during fluid-driven diffusion-reaction processes.

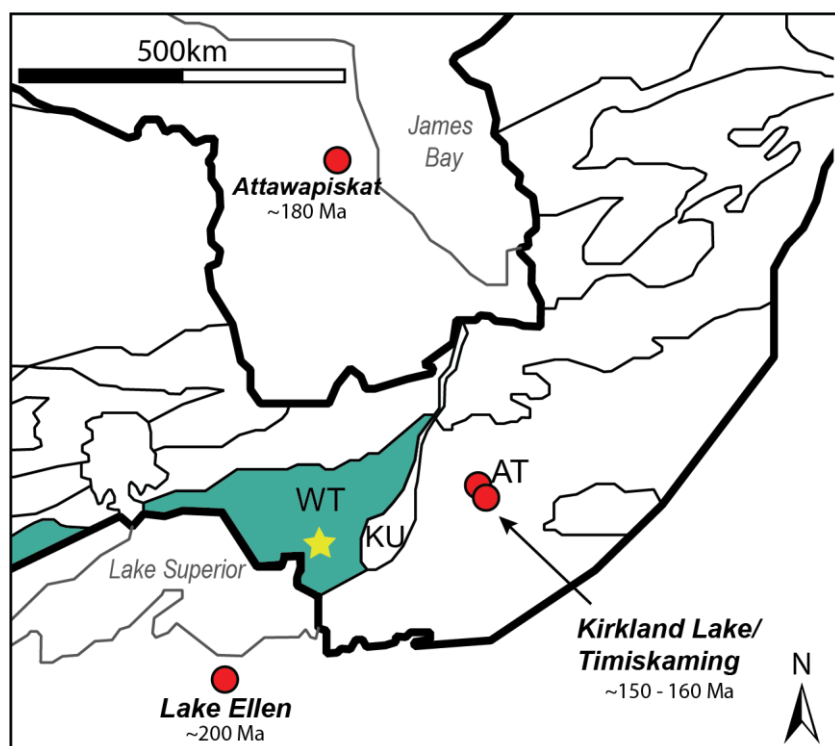


Figure 5.1: Simplified zoomed in map of the Superior Province with terranes outlines. Yellow star indicates location of MGB; WT = Wawa Terrane; AT = Abitibi Terrane; KU = Kapuskasing Uplift. Red circles are kimberlite dykes, location and age data from Heaman et al., 2004.

Geochronological evidence for this hotspot influence is restricted to sample 621. This suggests two possibilities: that fluid infiltration into Island Gold associated with this event was minimal, and that this study's sampling scope was not large enough to resolve more dates of this age range; or that the structural make-up of the vein sets at Island Gold is very particular and only a small subset of veins was impacted by this event.

In this discussion, two distinct events have been posited as origins of the young dates discovered at Island Gold. A final possibility to explain the presence of all dates younger than the protolith-age of ~2737 Ma, is that fluid activity associated with the Great Meteor Hotspot track and associated kimberlitic intrusions has resulted in various degrees of partial Pb loss across a range of samples, excluding sample 622-Group 2 which shows similarities in both U-Pb dates and trace elements to sample 628-Group 2 (carbonatite).

5.3 Implications for Gold Remobilization

The evidence for post-Archean fluid activity within the Island Gold deposit brings forward the possibility for late fluid-driven gold remobilization. Gold-remobilization requires fluid ingress that can scavenge gold from existing deposits, complex the gold with chemical ligands to allow transport of gold within the fluid, and then travel along structural conduits and undergo changes (such as pH changes, temperature changes, chemical changes, etc.) that result in gold precipitation (Williams-Jones et al., 2009). Fluid-driven remobilization of gold requires large amounts of fluid due to the low solubility of gold in aqueous solutions (~1ppm for magmatic fluids) and occurs by the dissolution-reprecipitation of minerals hosting gold (or dissolution of free-gold) from one location to another. This results in different generations of mineral formation that can be distinguished petrographically and with the use of LA-ICP-MS or SEM element maps (Fougerouse et al., 2016; Hastie et al., 2007).

Evidence of post-Archean activity is limited to primarily one sample from this thesis (sample 621), one sample from Ciufo (2019) (sample TY128) and one individual zircon each from samples 602 and 622. No petrographic evidence of mineral dissolution-reprecipitation was found in samples 621, 622, or 602, and no SEM or LA-ICP-MS elements maps of sulfides were conducted. Sample 621 does not contain notably different (higher or lower) concentrations of Au (Appendix F) and does not differ in its sulfur, oxygen, or hydrogen isotopes compared to other strongly altered samples. 621 also does not display any mineralogical or textural differences in petrography to other strongly altered samples. Therefore, no evidence supporting gold remobilization activity has been found in this study.

The small number of samples that record post-Archean activity may be a contributing factor to this lack of evidence of gold remobilization. However, if the post-Archean fluids had

the necessary chemical composition to scavenge, complex, mobilize, and reprecipitate gold within the deposit, the rarity of the post-Archean evidence suggests that this would have had a minimal impact on the gold endowment and distribution within the deposit.

6.0 Conclusions

The main focus of this thesis was to understand the origin of anomalously young ages within the Island gold deposit and elucidate the potential for associated gold remobilization. This involved establishing the U-Pb dates themselves, the spatial distribution of these dates, their zircon trace element characteristics, and connecting these young dates with geological events in the region. Below is a summary of the findings:

- Zircons that produced young ages are restricted to strongly altered dacite samples associated with auriferous V1-V2 veining, and are rare within the Island Gold deposit (4/33 samples analysed)
- Concordant clusters of post-Archean dates indicate two potential fluid ingress events:
 - First event at ~1138 Ma – 1021 Ma; these dates may be associated with MCR stresses and fluids sourced from the magmatic underplating.
 - Second event at ~243 Ma – 224 Ma; these dates may be associated with the Great Meteor Hotspot track and the associated magmatic activity (kimberlite intrusions in the region).
- Evidence of gold remobilization (dissolution-reprecipitation textures, mineralogical changes, change in light stable isotopes, etc.) were not discovered in any of the young samples. If gold remobilization did occur, it was likely minimal and does not impact the overall grade or distribution of gold within the deposit.

7.0 Future Work

More work can be accomplished to further elucidate the impact this late fluid activity may have had on gold re-mobilization within the deposit, to further characterize the fluid activity, and to refine the U-Pb geochronological results of this thesis.

- Apatite analyses; both U-Pb geochronology and trace element analyses. Apatite is more susceptible to fluid infiltration than zircon (Kirkland et al., 2018), and therefore analysing apatite could further elucidate the trace element characteristics of the late fluid activity
- Refine U-Pb geochronological results:
 - Use of shorter ablation times (~10s) with higher fluence for analysis; studies have shown that this can produce more accurate results by minimizing downhole fractionation (Mukherjee et al., 2019). This would need to be tested, as shorter ablation times could hinder the counting statistics of the isotopes being measured, particularly uranium on the Faraday cup detectors.
 - Use of analysis techniques that are specialized for small spot sizes, such as NanoSIMS or AtomProbe (Takahata et al., 2008; Valley et al., 2015).
- Trace element analyses on the zircons that produce dates between ~2760 and ~2700 Ma, to confirm the interpretation that these dates are due to analytical error or minor Pb loss. Trace element concentrations similar to those with protolith-aged dates would support this interpretation, as different trace element concentrations would indicate an alternate process in play (possibly alteration).
- Further sample collection and U-Pb analysis with the goal of finding more post-Archean dates within Island Gold. Increasing the number of zircons that produce post-Archean

dates will further clarify the extent of late fluid activity and can help to constrain the fluid activity time periods.

- Detailed analysis of the immediate surrounding area around sample 621, in which most post-Archean dates are found. The paucity of post-Archean dates throughout the study area may indicate that the section of the mine where sample 621 was collected differs from other areas, making it susceptible to late-fluid activity. This possibility can be explored through detailed study of the sampling location in terms of its structural features, petrology, and further sample collection for additional U-Pb analyses.

References

- Bas, M.J.L., Maitre, R.W.L., Streckeisen, A., Zanettin, B., IUGS Subcommission on the Systematics of Igneous Rocks, 1986. A Chemical Classification of Volcanic Rocks Based on the Total Alkali-Silica Diagram. *J. Petrol.* 27, 745–750. <https://doi.org/10.1093/petrology/27.3.745>
- Bédard, J.H., Harris, L.B., Thurston, P.C., 2013. The hunting of the snArc. *Precambrian Res., Evolving Early Earth* 229, 20–48. <https://doi.org/10.1016/j.precamres.2012.04.001>
- Bourgeault, N., Vincent, R., Webster, C., Lincoln, N., 2022. NI 43-101 Technical Report for the Island Gold Mine, Dubreuilville, Ontario, Canada.
- Card, K.D., 1990. A review of the Superior Province of the Canadian Shield, a product of Archean accretion. *Precambrian Res.* 48, 99–156. [https://doi.org/10.1016/0301-9268\(90\)90059-Y](https://doi.org/10.1016/0301-9268(90)90059-Y)
- Chang, Z., Vervoort, J.D., McClelland, W.C., Knaack, C., 2006. U-Pb dating of zircon by LA-ICP-MS. *Geochem. Geophys. Geosystems* 7. <https://doi.org/10.1029/2005GC001100>
- Ciufo, T.J., 2019. Hydrothermal Alteration and Exploration Vectors at the Island Gold Deposit, Michipicoten Greenstone Belt, Wawa, Ontario.
- Ciufo, T.J., Yakymchuk, C., Lin, S., Jellicoe, K., Mercier-Langevin, P., 2019. Hydrothermal alteration and vectors at the orogenic Island Gold deposit, Michipicoten greenstone belt, Wawa, Ontario, in: Rogers, N. (Ed.), Targeted Geoscience Initiative: 2017 Report of Activities, Open File 8358. Geological Survey of Canada, pp. 117–120. <https://doi.org/10.4095/306391>

Davis, D.W., 2002. U–Pb geochronology of Archean metasedimentary rocks in the Pontiac and Abitibi subprovinces, Quebec, constraints on timing, provenance and regional tectonics. *Precambrian Res.* 115, 97–117. [https://doi.org/10.1016/S0301-9268\(02\)00007-4](https://doi.org/10.1016/S0301-9268(02)00007-4)

Deer, W.A., Howie, R., A., Zussman, J., 1982. *Rock-Forming Minerals: Orthosilicates*, 2nd ed. The Geological Society of London.

Elliott, H.A.L., Wall, F., Chakhmouradian, A.R., Siegfried, P.R., Dahlgren, S., Weatherley, S., Finch, A.A., Marks, M.A.W., Dowman, E., Deady, E., 2018. Fenites associated with carbonatite complexes: A review. *Ore Geol. Rev.* 93, 38–59. <https://doi.org/10.1016/j.oregeorev.2017.12.003>

Ernst, R., Bleeker, W., 2010. Large igneous provinces (LIPs), giant dyke swarms, and mantle plumes: significance for breakup events within Canada and adjacent regions from 2.5 Ga to the Present. *Can. J. Earth Sci.* 47, 695–739. <https://doi.org/10.1139/E10-025>

Ernst, R.E., Buchan, K.L., 1993. Paleomagnetism of the Abitibi dyke swarm, southern Superior Province, and implications for the Logan Loop. *Can. J. Earth Sci.* 30, 1886–1897. <https://doi.org/10.1139/e93-167>

Fougerouse, D., Micklethwaite, S., Tomkins, A.G., Mei, Y., Kilburn, M., Guagliardo, P., Fisher, L.A., Halfpenny, A., Gee, M., Paterson, D., Howard, D.L., 2016. Gold remobilisation and formation of high grade ore shoots driven by dissolution-reprecipitation replacement and Ni substitution into auriferous arsenopyrite. *Geochim. Cosmochim. Acta* 178, 143–159. <https://doi.org/10.1016/j.gca.2016.01.040>

Gaboury, D., 2019. Parameters for the formation of orogenic gold deposits. *Appl. Earth Sci.* 128, 124–133. <https://doi.org/10.1080/25726838.2019.1583310>

Geisler, T., Pidgeon, R.T., Van Bronswijk, W., Kurtz, R., 2002. Transport of uranium, thorium, and lead in metamict zircon under low-temperature hydrothermal conditions. *Chem. Geol.* 191, 141–154. [https://doi.org/10.1016/S0009-2541\(02\)00153-5](https://doi.org/10.1016/S0009-2541(02)00153-5)

Geisler, T., Rashwan, A.A., Rahn, M.K.W., Poller, U., Zwingmann, H., Pidgeon, R.T., Schleicher, H., Tomaschek, F., 2003. Low-temperature hydrothermal alteration of natural metamict zircons from the Eastern Desert, Egypt. *Mineral. Mag.* 67, 485–508. <https://doi.org/10.1180/0026461036730112>

Geisler, T., Schaltegger, U., Tomaschek, F., 2007. Re-equilibration of Zircon in Aqueous Fluids and Melts. *Elements* 3, 43–50. <https://doi.org/10.2113/gselements.3.1.43>

Goldfarb, R.J., Groves, D.I., 2015. Orogenic gold: Common or evolving fluid and metal sources through time. *Lithos* 233, 2–26. <https://doi.org/10.1016/j.lithos.2015.07.011>

Grant, M.L., Wilde, S.A., Wu, F., Yang, J., 2009. The application of zircon cathodoluminescence imaging, Th–U–Pb chemistry and U–Pb ages in interpreting discrete magmatic and high-grade metamorphic events in the North China Craton at the Archean/Proterozoic boundary. *Chem. Geol., The Application and Interpretation of Micro-analytical Data in Geochronological Systems* 261, 155–171. <https://doi.org/10.1016/j.chemgeo.2008.11.002>

Groves, D.I., Goldfarb, R.J., Gebre-Mariam, M., Hagemann, S.G., Robert, F., 1998. Orogenic gold deposits: A proposed classification in the context of their crustal distribution and relationship to other gold deposit types. *Ore Geol. Rev.* 13, 7–27. [https://doi.org/10.1016/S0169-1368\(97\)00012-7](https://doi.org/10.1016/S0169-1368(97)00012-7)

Groves, D.I., Santosh, M., Goldfarb, R.J., Zhang, L., 2018. Structural geometry of orogenic gold deposits: Implications for exploration of world-class and giant deposits. *Geosci. Front.* 9, 1163–1177. <https://doi.org/10.1016/j.gsf.2018.01.006>

Harley, S.L., Kelly, N.M., Moller, A., 2007. Zircon Behaviour and the Thermal Histories of Mountain Chains. *Elements* 3, 25–30. <https://doi.org/10.2113/gselements.3.1.25>

Hastie, A.R., Kerr, A.C., Pearce, J.A., Mitchell, S.F., 2007. Classification of Altered Volcanic Island Arc Rocks using Immobile Trace Elements: Development of the Th–Co Discrimination Diagram. *J. Petrol.* 48, 2341–2357. <https://doi.org/10.1093/petrology/egm062>

Heaman, L.M., Kjarsgaard, B.A., Creaser, R.A., 2004. The temporal evolution of North American kimberlites. *Lithos* 76, 377–397. <https://doi.org/10.1016/j.lithos.2004.03.047>

Heather, K.B., Arias, Z., 1992. Geological and structural setting of gold mineralization in the Goudreau-Lochalsh area, Wawa gold camp. Ontario Geological Survey, Ministry of Northern Development and Mines.

Hoefs, J., 2021. Isotope Fractionation Processes of Selected Elements, in: Hoefs, J. (Ed.), *Stable Isotope Geochemistry*, Springer Textbooks in Earth Sciences, Geography and Environment. Springer International Publishing, Cham, pp. 49–265. https://doi.org/10.1007/978-3-030-77692-3_2

Horn, I., Rudnick, R.L., McDonough, W.F., 2000. Precise elemental and isotope ratio determination by simultaneous solution nebulization and laser ablation-ICP-MS: application to U–Pb geochronology. *Chem. Geol.* 164, 281–301. [https://doi.org/10.1016/S0009-2541\(99\)00168-0](https://doi.org/10.1016/S0009-2541(99)00168-0)

Horstwood, M.S.A., Košler, J., Gehrels, G., Jackson, S.E., McLean, N.M., Paton, C., Pearson, N.J., Sircombe, K., Sylvester, P., Vermeesch, P., Bowring, J.F., Condon, D.J., Schoene, B., 2016. Community-Derived Standards for LA - ICP - MS U-(Th-)Pb Geochronology – Uncertainty Propagation, Age Interpretation and Data Reporting. *Geostand. Geoanalytical Res.* 40, 311–332. <https://doi.org/10.1111/j.1751-908X.2016.00379.x>

Hynes, A., Rivers, T., 2010. Protracted continental collision — evidence from the Grenville Orogen. *Can. J. Earth Sci.* 47, 591–620. <https://doi.org/10.1139/E10-003>

Jellicoe, K., 2019. Structural Controls and Deformation History of the Orogenic Island Gold Deposit, Michipicoten Greenstone Belt, Ontario.

Jellicoe, K., Ciufo, T.J., Lin, S., Wodicka, N., Wu, N., Mercier-Langevin, P., Yakymchuk, C., 2022. Genesis of the Island Gold Deposit, Ontario, Canada: Implications for Gold Mineralization in the Wawa Subprovince of the Superior Province. *Econ. Geol.* 117, 1597–1612. <https://doi.org/10.5382/econgeo.4963>

Jellicoe, K., Lin, S., Ciufo, T.J., Yakymchuk, C., Mercier-Langevin, P., 2018. Structural controls and relative timing of events at the orogenic Island Gold deposit, Michipicoten greenstone belt, Wawa, Ontario, in: Rogers, N. (Ed.), Targeted Geoscience Initiative: 2017 Report of Activities, Open File 8358. Geological Survey of Canada, pp. 113–116. <https://doi.org/10.4095/306391>

Kirkland, C.L., Yakymchuk, C., Szilas, K., Evans, N., Hollis, J., McDonald, B., Gardiner, N.J., 2018. Apatite: a U-Pb thermochronometer or geochronometer? *Lithos* 318–319, 143–157. <https://doi.org/10.1016/j.lithos.2018.08.007>

Košler, J., Sylvester, P.J., 2003. 9. Present Trends and the Future of Zircon in Geochronology: Laser Ablation ICPMS, in: Hanchar, J.M., Hoskin, P.W.O. (Eds.), *Zircon*. De Gruyter, pp. 243–276. <https://doi.org/10.1515/9781501509322-012>

Le Maitre, R.W., Streckeisen, A., Zanettin, B., Le Bas, M.J., Bonin, B., Bateman, P. (Eds.), 2002. *Igneous Rocks: A Classification and Glossary of Terms*, 2nd ed. Cambridge University Press, Cambridge. <https://doi.org/10.1017/CBO9780511535581>

Lodge, R.W.D., 2016. Petrogenesis of intermediate volcanic assemblages from the Shebandowan greenstone belt, Superior Province: Evidence for subduction during the Neoarchean. *Precambrian Res.* 272, 150–167. <https://doi.org/10.1016/j.precamres.2015.10.018>

McDannell, K.T., Zeitler, P.K., Schneider, D.A., 2018. Instability of the southern Canadian Shield during the late Proterozoic. *Earth Planet. Sci. Lett.* 490, 100–109. <https://doi.org/10.1016/j.epsl.2018.03.012>

Mole, D.R., Thurston, P.C., Marsh, J.H., Stern, R.A., Ayer, J.A., Martin, L.A.J., Lu, Y.J., 2021. The formation of Neoarchean continental crust in the south-east Superior Craton by two distinct geodynamic processes. *Precambrian Res.* 356, 106104. <https://doi.org/10.1016/j.precamres.2021.106104>

Moser, D.E., 1994. The geology and structure of the mid-crustal Wawa gneiss domain: a key to understanding tectonic variation with depth and time in the late Archean Abitibi–Wawa orogen. *Can. J. Earth Sci.* 31, 1064–1080. <https://doi.org/10.1139/e94-096>

Mukherjee, P., K., Kate Souders, A., Sylvester, P., J., 2019. Accuracy and precision of U–Pb zircon geochronology at high spatial resolution (7–20 μm spots) by laser ablation-ICP-

single-collector-sector-field-mass spectrometry. *J. Anal. At. Spectrom.* 34, 180–192.

<https://doi.org/10.1039/C8JA00321A>

Paton, C., Woodhead, J.D., Hellstrom, J.C., Hergt, J.M., Greig, A., Maas, R., 2010. Improved laser ablation U-Pb zircon geochronology through robust downhole fractionation correction. *Geochem. Geophys. Geosystems* 11. <https://doi.org/10.1029/2009GC002618>

Percival, J.A., 2007. *Geology and Metallogeny of the Superior Province Canada*, in: Goodfellow, W.D. (Ed.), *Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of the Geological Provinces, and Exploration Methods*. Geological Association of Canada: Mineral Deposits Division.

Percival, J.A., Skulski, T., Sandborn-Barrie, M., Stott, G.M., Leclair, A.D., Corkery, M.T., Boily, M., 2012. *Geology and tectonic evolution of the Superior Province, Canada*, in: Percival, J.A., Cook, F.A., Clowes, R.M. (Eds.), *Tectonic Styles in Canada: The LITHOPROBE Perspective*, Special Paper 49. Geological Association of Canada, pp. 321–378.

Percival, J.A., West, G.F., 1994. The Kapuskasing uplift: a geological and geophysical synthesis. *Can. J. Earth Sci.* 31, 1256–1286. <https://doi.org/10.1139/e94-110>

Phillips, G.N., Powell, R., 2010. Formation of gold deposits: a metamorphic devolatilization model: FORMATION OF GOLD DEPOSITS. *J. Metamorph. Geol.* 28, 689–718. <https://doi.org/10.1111/j.1525-1314.2010.00887.x>

Polat, A., 2009. The geochemistry of Neoarchean (ca. 2700Ma) tholeiitic basalts, transitional to alkaline basalts, and gabbros, Wawa Subprovince, Canada: Implications for petrogenetic and geodynamic processes. *Precambrian Res.* 168, 83–105. <https://doi.org/10.1016/j.precamres.2008.03.008>

Rice, R.J., Donaldson, J.A., 1992. Sedimentology of the Archean Doré metasediments, Arliss Lake area, southern Michipicoten greenstone belt, Superior Province. *Can. J. Earth Sci.* 29, 2558–2570. <https://doi.org/10.1139/e92-203>

Sage, R.P., Lightfoot, P.C., Doherty, W., 1996. Bimodal cyclical Archean basalts and rhyolites from the Michipicoten (Wawa) greenstone belt, Ontario: geochemical evidence for magma contributions from the asthenospheric mantle and ancient continental lithosphere near the southern margin of the Superior Province. *Precambrian Res.* 76, 119–153. [https://doi.org/10.1016/0301-9268\(95\)00020-8](https://doi.org/10.1016/0301-9268(95)00020-8)

Sage, R. P., Lightfoot, P.C., Doherty, W., 1996. Geochemical characteristics of granitoid rocks from within the Archean Michipicoten Greenstone Belt, Wawa Subprovince, Superior Province, Canada: implications for source regions and tectonic evolution. *Precambrian Res.* 76, 155–190. [https://doi.org/10.1016/0301-9268\(95\)00021-6](https://doi.org/10.1016/0301-9268(95)00021-6)

Sheppard, S., 1986. Characterization and isotopic variations in natural waters. *Stable Isot. High Temp. Geol. Process.* 16, 165–183.

Sláma, J., Košler, J., Condon, D.J., Crowley, J.L., Gerdes, A., Hanchar, J.M., Horstwood, M.S.A., Morris, G.A., Nasdala, L., Norberg, N., Schaltegger, U., Schoene, B., Tubrett, M.N., Whitehouse, M.J., 2008. Plešovice zircon — A new natural reference material for U–Pb and Hf isotopic microanalysis. *Chem. Geol.* 249, 1–35. <https://doi.org/10.1016/j.chemgeo.2007.11.005>

Sokół, K., Finch, A.A., Hutchison, W., Cloutier, J., Borst, A.M., Humphreys, M.C.S., 2021. Quantifying metasomatic high-field-strength and rare-earth element transport from alkaline magmas. *Geology* 50, 305–310. <https://doi.org/10.1130/G49471.1>

Spencer, C.J., Yakymchuk, C., Ghaznavi, M., 2017. Visualising data distributions with kernel density estimation and reduced chi-squared statistic. *Geosci. Front.* 8, 1247–1252.

<https://doi.org/10.1016/j.gsf.2017.05.002>

Sun, S.-s., McDonough, W.F., 1989. Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. *Geol. Soc. Lond. Spec. Publ.* 42, 313–345. <https://doi.org/10.1144/GSL.SP.1989.042.01.19>

Takahata, N., Tsutsumi, Y., Sano, Y., 2008. Ion microprobe U–Pb dating of zircon with a 15 micrometer spatial resolution using NanoSIMS. *Gondwana Res., Micro-chronology and evolution of the planet Earth* 14, 587–596. <https://doi.org/10.1016/j.gr.2008.01.007>

Tomkins, A.G., 2013. On the source of orogenic gold. *Geology* 41, 1255–1256. <https://doi.org/10.1130/focus122013.1>

Tomlinson, K.Y., Davis, D.W., Stone, D., Hart, T.R., 2003. U–Pb age and Nd isotopic evidence for Archean terrane development and crustal recycling in the south-central Wabigoon subprovince, Canada. *Contrib. Mineral. Petrol.* 144, 684–702. <https://doi.org/10.1007/s00410-002-0423-0>

Turek, A., Smith, P.E., Schmus, W.R.V., 1984. U–Pb zircon ages and the evolution of the Michipicoten plutonic–volcanic terrane of the Superior Province, Ontario. *Can. J. Earth Sci.* 21, 457–464. <https://doi.org/10.1139/e84-049>

Turek, A., Smith, P.E., Schmus, W.R.V., 1982. Rb–Sr and U–Pb ages of volcanism and granite emplacement in the Michipicoten belt—Wawa, Ontario. *Can. J. Earth Sci.* 19, 1608–1626. <https://doi.org/10.1139/e82-138>

Valley, J.W., Reinhard, D.A., Cavosie, A.J., Ushikubo, T., Lawrence, D.F., Larson, D.J., Kelly, T.F., Snoeyenbos, D.R., Strickland, A., 2015. Nano- and micro-geochronology in Hadean and Archean zircons by atom-probe tomography and SIMS: New tools for old minerals. *Am. Mineral.* 100, 1355–1377. <https://doi.org/10.2138/am-2015-5134>

Vermeesch, P., 2021. On the treatment of discordant detrital zircon U–Pb data. *Geochronology* 3, 247–257. <https://doi.org/10.5194/gchron-3-247-2021>

Wiedenbeck, M., Allé, P., Corfu, F., Griffin, W. I., Meier, M., Oberli, F., Quadt, A.V., Roddick, J. C., Spiegel, W., 1995. Three Natural Zircon Standards for U-Th-Pb, Lu-Hf, Trace Element and Re Analysis. *Geostand. Newsl.* 19, 1–23. <https://doi.org/10.1111/j.1751-908X.1995.tb00147.x>

Williams, H.R., Stott, G.M., Heather, K.B., Muir, T.L., Sage, R.P., 1991. Wawa Subprovince, in: Thurston, P.C., Williams, H.R., Sutcliffe, R.H., Stott, G.M. (Eds.), *Geology of Ontario*; Ontario Geological Survey, Special Volume 4, Part 1. pp. 485–539.

Williams-Jones, A.E., Bowtell, R.J., Migdisov, A.A., 2009. Gold in Solution. *Elements* 5, 281–287. <https://doi.org/10.2113/gselements.5.5.281>

Xu, C., Kynicky, J., Chakhmouradian, A.R., Campbell, I.H., Allen, C.M., 2010. Trace-element modeling of the magmatic evolution of rare-earth-rich carbonatite from the Miaoya deposit, Central China. *Lithos* 118, 145–155. <https://doi.org/10.1016/j.lithos.2010.04.003>

Appendix A: U-Pb Secondary standard concordia diagrams

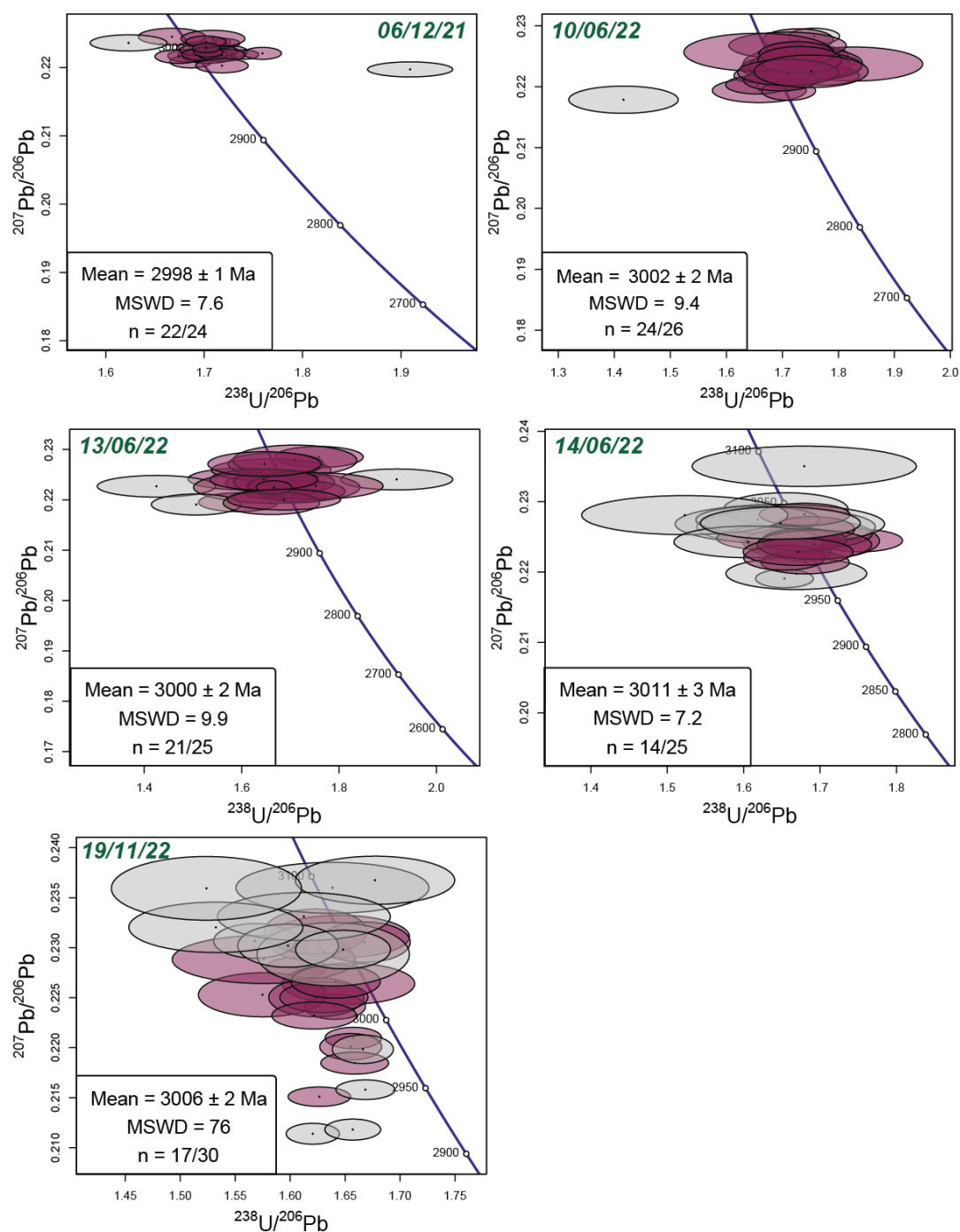


Figure A.1: Secondary reference material DD85; Tera-Wasserburg concordia plots with weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ ages, number of zircons analysed (n), and MSWD from each analysis session. Ellipses in red are included in the weighted mean age calculation while those in grey are excluded from the weighted mean age calculation

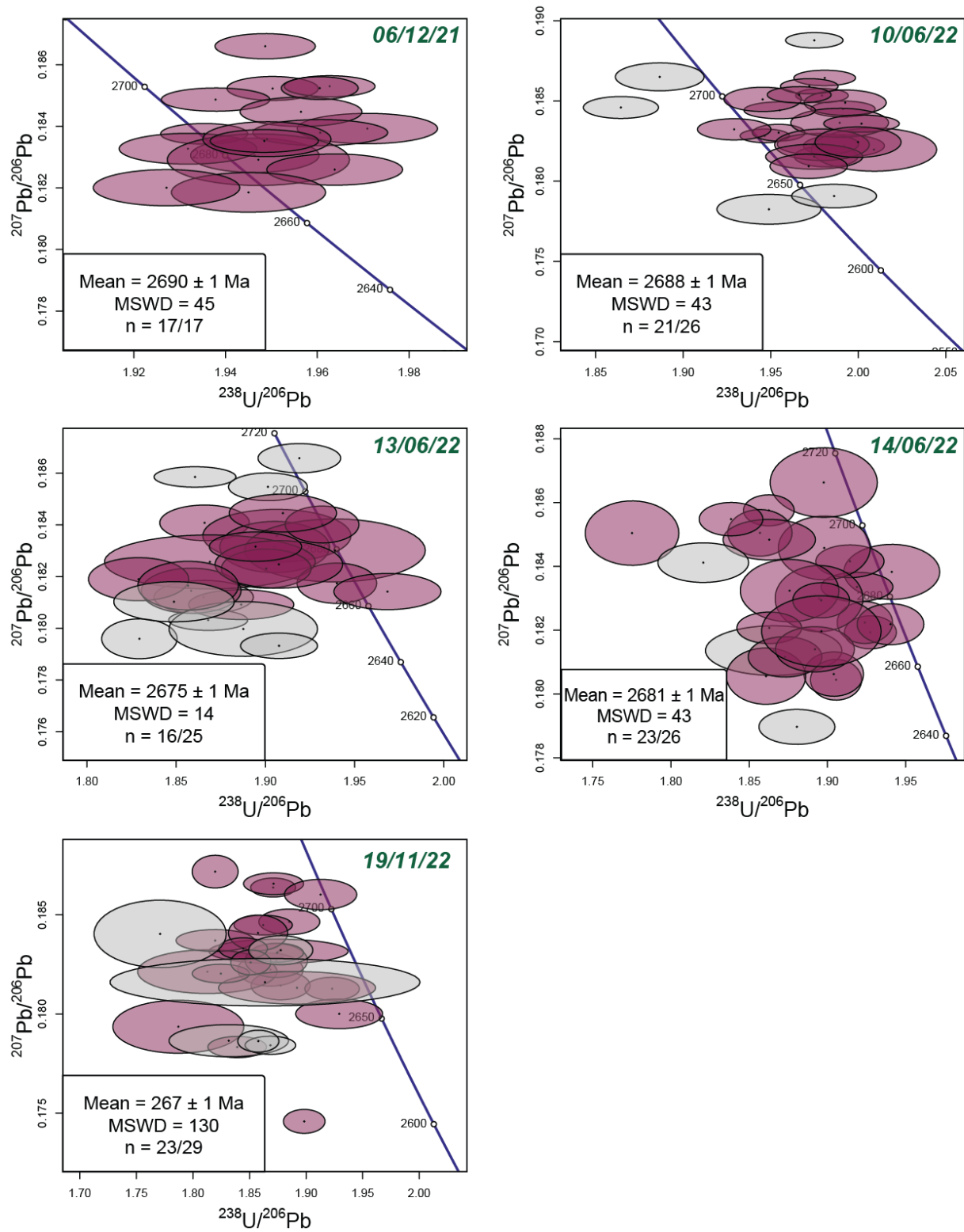


Figure A.2: Secondary reference material DD91; Tera-Wasserburg concordia plots with weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ ages, number of zircons analysed (n), and MSWD from each analysis session. Ellipses in red are included in the weighted mean age calculation while those in grey are excluded from the weighted mean age calculation.

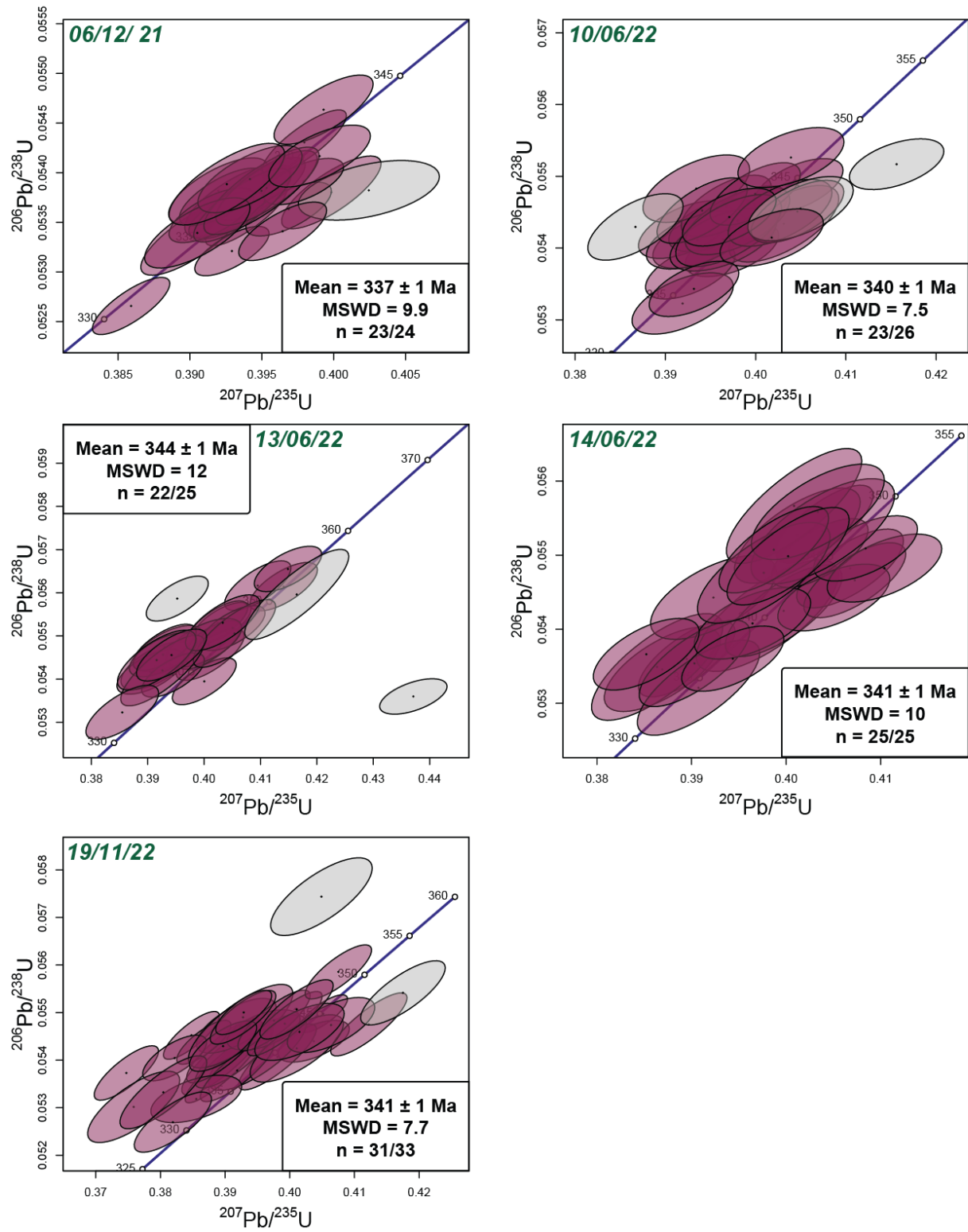


Figure A.3: Secondary reference material Plesovice; Wetherill concordia plots with weighted mean $^{206}\text{Pb}/^{238}\text{U}$ ages, number of zircons analysed (n), and MSWD from each analysis session. Ellipses in red are included in the weighted mean age calculation while those in grey are excluded from the weighted mean age calculation.

Appendix B: LA-ICP-MS U-Pb Isotope Data, and U-Pb Age Data

See Section 3.3 for methodology.

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
	601 (least altered)															
601-1	0.537	0.011	14.001	0.319	0.190	0.001	1.872	0.040	2749	21	2759	48	2742	9	57.989	2.404
601-2	0.553	0.018	14.429	0.466	0.192	0.001	1.845	0.057	2774	30	2792	70	2760	12	34.654	1.616
601-3	0.516	0.013	13.498	0.360	0.190	0.001	1.949	0.048	2713	24	2670	54	2745	9	52.663	3.350
601-4	0.581	0.031	15.044	0.791	0.190	0.001	1.850	0.071	2762	37	2786	87	2744	12	28.721	1.561
601-5	0.566	0.021	14.594	0.521	0.191	0.001	1.831	0.062	2773	33	2809	77	2746	12	34.669	1.829
601-6	0.558	0.017	14.488	0.452	0.189	0.001	1.830	0.047	2767	25	2811	59	2734	10	43.409	2.173
601-7	0.551	0.012	14.464	0.334	0.190	0.001	1.818	0.040	2779	22	2826	51	2746	9	52.871	1.986
601-8	0.625	0.078	15.975	1.902	0.191	0.002	1.896	0.127	2740	64	2730	150	2746	16	17.987	1.375
601-9*	0.539	0.016	13.748	0.413	0.184	0.001	1.856	0.049	2726	26	2779	60	2688	13	36.820	1.770
601-10*	0.531	0.008	13.579	0.207	0.184	0.001	1.876	0.029	2718	15	2755	34	2691	7	89.918	5.420
	602 (weakly altered)															
602-1	0.521	0.009	13.211	0.239	0.183	0.001	1.920	0.032	2692	16	2702	37	2684	7	74.052	2.255
602-2*	0.572	0.020	14.547	0.507	0.184	0.001	1.798	0.057	2758	31	2850	73	2692	12	34.342	1.700
602-3	0.541	0.009	13.799	0.251	0.185	0.001	1.844	0.030	2736	16	2794	37	2693	8	76.164	4.442
602-4*	0.558	0.016	14.419	0.432	0.186	0.001	1.820	0.048	2754	25	2823	60	2703	10	47.083	3.829
602-5	0.545	0.011	13.975	0.302	0.185	0.001	1.840	0.035	2739	18	2798	43	2697	8	55.156	1.733
602-6	0.572	0.010	14.644	0.265	0.184	0.001	1.739	0.029	2791	16	2928	39	2693	6	91.117	2.860
602-7	0.558	0.009	14.452	0.258	0.191	0.001	1.798	0.031	2790	17	2851	40	2747	9	100.374	2.903
602-8	0.552	0.007	14.243	0.203	0.189	0.001	1.816	0.025	2772	13	2828	31	2731	6	162.292	4.465
602-9	0.537	0.013	13.866	0.354	0.189	0.001	1.890	0.045	2734	23	2738	53	2731	9	60.843	3.238
602-10	0.551	0.006	14.221	0.173	0.190	0.001	1.820	0.021	2775	11	2823	26	2741	5	206.529	14.106
602-11**	0.088	0.001	0.726	0.011	0.061	0.001	11.411	0.165	558	8	542	8	624	25	360.918	5.603
602-12	0.540	0.014	13.984	0.382	0.190	0.001	1.871	0.043	2748	23	2760	52	2739	10	53.122	3.002

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
602-13	0.556	0.018	14.236	0.471	0.189	0.001	1.838	0.053	2759	28	2801	66	2729	11	38.103	2.051
602-14	0.595	0.037	15.161	0.913	0.188	0.001	1.842	0.064	2755	33	2796	79	2725	11	42.775	3.822
602-15	0.549	0.011	14.188	0.296	0.189	0.001	1.827	0.035	2768	18	2815	43	2734	7	117.854	11.460
602-16	0.508	0.009	13.092	0.232	0.189	0.001	1.969	0.032	2695	16	2647	36	2731	7	101.889	6.134
602-17	0.553	0.012	14.333	0.345	0.190	0.001	1.826	0.038	2773	21	2816	48	2742	10	59.791	2.153
602-18	0.535	0.015	14.332	0.420	0.191	0.001	1.882	0.051	2751	27	2748	61	2753	12	43.038	1.803
602-19	0.534	0.006	14.055	0.171	0.191	0.001	1.876	0.023	2750	12	2755	27	2746	6	158.874	7.662
602-20	0.527	0.007	13.911	0.202	0.192	0.001	1.907	0.025	2740	13	2718	29	2756	6	195.296	20.329
602-21	0.532	0.010	14.102	0.286	0.191	0.001	1.870	0.035	2757	19	2762	43	2754	9	73.602	2.971
602-22	0.546	0.006	14.328	0.162	0.190	0.001	1.832	0.020	2770	11	2807	25	2743	5	197.892	8.467
602-23*	0.635	0.067	16.942	1.796	0.192	0.002	1.840	0.093	2775	49	2798	115	2758	16	24.313	1.454
602-24	0.531	0.007	14.009	0.193	0.191	0.001	1.891	0.024	2743	13	2736	29	2748	7	113.451	8.131
602-25	0.593	0.009	15.656	0.253	0.191	0.001	1.687	0.026	2850	15	3000	36	2746	7	106.995	2.482
602-26	0.601	0.016	15.729	0.413	0.190	0.001	1.711	0.042	2836	24	2967	59	2744	8	49.232	3.450
602-27	0.557	0.012	14.386	0.327	0.187	0.001	1.807	0.038	2766	21	2840	49	2713	9	68.605	2.099
602-28	0.531	0.008	13.943	0.199	0.189	0.001	1.881	0.028	2742	15	2748	34	2737	8	82.693	3.159
602-29	0.548	0.012	14.147	0.327	0.187	0.001	1.859	0.033	2738	17	2775	39	2711	9	75.394	4.334
602-30	0.508	0.015	13.175	0.358	0.188	0.001	1.992	0.063	2683	31	2622	69	2728	11	54.745	2.003
602-31	0.564	0.008	14.767	0.215	0.190	0.001	1.774	0.027	2799	15	2882	35	2739	5	285.354	32.392
602-32	0.595	0.036	15.577	0.938	0.190	0.001	1.799	0.059	2785	32	2850	75	2739	11	36.255	1.808
602-33	0.558	0.011	14.544	0.294	0.190	0.001	1.805	0.036	2782	19	2842	46	2738	7	108.084	8.393
	603 (strongly altered)															
603-1	0.539	0.023	14.113	0.584	0.189	0.001	1.943	0.069	2709	34	2676	78	2734	12	35.303	1.753
603-2	0.509	0.005	13.060	0.148	0.187	0.001	1.966	0.021	2689	11	2651	23	2718	6	215.656	7.350
603-3	0.505	0.008	12.998	0.208	0.187	0.001	1.979	0.028	2682	14	2637	31	2715	7	134.586	5.354
603-4	0.540	0.007	14.019	0.197	0.189	0.001	1.849	0.026	2755	14	2788	31	2731	7	103.817	7.040
	604 (least altered)															
604-1	0.549	0.008	14.347	0.213	0.190	0.001	1.816	0.025	2777	14	2828	32	2740	7	87.234	3.763

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
604-2	0.538	0.010	14.021	0.296	0.190	0.001	1.862	0.037	2753	20	2772	45	2740	10	61.494	3.203
604-3	0.553	0.014	14.508	0.375	0.192	0.001	1.830	0.044	2779	23	2811	55	2756	10	49.466	1.566
604-4	0.568	0.027	14.805	0.702	0.190	0.001	1.858	0.066	2758	34	2776	80	2745	12	32.665	1.702
604-5	0.555	0.026	14.543	0.711	0.191	0.002	1.835	0.082	2772	43	2805	101	2749	14	27.780	1.579
604-7	0.572	0.013	15.126	0.372	0.194	0.001	1.743	0.039	2835	22	2924	53	2772	10	66.395	3.394
604-8	0.547	0.008	14.400	0.211	0.192	0.001	1.816	0.024	2789	13	2828	30	2760	7	102.906	5.490
604-9	0.569	0.008	14.878	0.247	0.191	0.001	1.747	0.025	2821	14	2918	34	2751	7	98.034	5.256
	607 (least altered)															
607-1	0.531	0.009	14.157	0.250	0.193	0.001	1.895	0.030	2753	16	2732	35	2769	9	30.460	0.815
607-2	0.530	0.006	13.953	0.162	0.191	0.001	1.889	0.020	2744	11	2739	24	2748	7	45.165	1.023
607-3	0.530	0.004	14.066	0.120	0.193	0.001	1.886	0.016	2754	8	2742	19	2763	5	90.369	2.224
607-4	0.527	0.005	13.999	0.142	0.193	0.001	1.896	0.018	2749	10	2731	21	2763	7	62.423	2.384
607-5	0.542	0.008	14.135	0.203	0.189	0.001	1.849	0.028	2758	15	2787	34	2737	7	28.185	0.873
607-6*	0.545	0.009	14.443	0.244	0.194	0.001	1.822	0.029	2794	16	2821	36	2774	10	65.276	2.034
607-7	0.591	0.019	15.449	0.490	0.191	0.001	1.709	0.050	2842	29	2969	70	2752	11	41.676	2.379
607-8	0.616	0.083	16.297	2.225	0.193	0.002	1.852	0.072	2772	38	2784	88	2764	15	25.393	1.377
607-9	0.549	0.009	14.457	0.238	0.193	0.001	1.815	0.027	2791	15	2830	34	2763	7	87.727	2.222
607-10	0.578	0.026	15.121	0.725	0.191	0.002	1.812	0.069	2784	37	2832	88	2749	14	29.686	1.625
607-11	0.550	0.014	14.344	0.405	0.189	0.001	1.828	0.048	2769	26	2813	59	2737	11	54.413	1.994
607-12	0.539	0.005	14.024	0.143	0.190	0.001	1.840	0.019	2763	10	2798	23	2738	6	156.029	8.341
607-13	0.593	0.033	15.488	0.854	0.191	0.001	1.822	0.071	2782	38	2821	89	2754	12	32.813	2.069
607-14	0.558	0.014	14.719	0.399	0.192	0.001	1.792	0.042	2801	23	2858	54	2761	10	47.088	2.086
607-15	0.556	0.021	14.493	0.582	0.190	0.001	1.839	0.056	2765	30	2799	70	2740	13	34.656	1.526
	608 (weakly altered)															
608-1	0.529	0.004	14.091	0.129	0.193	0.001	1.891	0.016	2754	9	2736	19	2768	4	112.918	4.494
608-2	0.522	0.007	13.562	0.184	0.189	0.001	1.926	0.027	2718	14	2696	31	2734	7	32.782	1.442
608-3	0.524	0.003	13.668	0.087	0.189	0.001	1.905	0.011	2730	6	2720	13	2737	5	89.882	1.390
608-4	0.550	0.012	14.571	0.335	0.193	0.001	1.811	0.037	2795	20	2834	47	2768	9	54.433	2.671

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
608-5	0.543	0.014	14.175	0.351	0.191	0.001	1.834	0.041	2772	23	2805	51	2748	12	54.100	3.337
608-6	0.584	0.038	15.160	0.992	0.189	0.002	1.875	0.071	2744	37	2755	84	2736	14	29.742	1.498
608-7	0.564	0.016	14.577	0.416	0.190	0.001	1.790	0.049	2791	27	2861	63	2740	11	46.186	2.550
608-8	0.559	0.025	14.782	0.643	0.192	0.002	1.882	0.067	2754	35	2748	80	2759	14	34.936	1.465
608-9	0.619	0.067	16.180	1.688	0.189	0.002	1.793	0.085	2786	46	2857	109	2735	14	26.689	1.645
608-10	0.540	0.007	14.129	0.192	0.190	0.001	1.845	0.025	2763	13	2792	30	2742	7	104.500	3.565
608-11	0.620	0.062	15.744	1.487	0.187	0.002	1.888	0.116	2727	59	2740	137	2717	15	20.575	1.434
608-12	0.537	0.007	14.063	0.196	0.190	0.001	1.848	0.024	2762	13	2788	29	2743	7	117.871	3.388
608-13	0.585	0.029	15.262	0.764	0.192	0.002	1.799	0.075	2795	41	2850	96	2756	14	28.643	1.611
608-14	0.599	0.039	15.338	0.964	0.187	0.002	1.844	0.087	2748	45	2793	107	2715	15	27.368	1.650
608-15	0.579	0.024	15.589	0.662	0.194	0.002	1.806	0.068	2804	37	2840	86	2779	17	30.194	1.491
608-16	0.613	0.034	16.053	0.861	0.190	0.002	1.767	0.073	2804	40	2892	97	2742	14	31.250	1.823
608-17	0.549	0.015	14.437	0.406	0.190	0.001	1.844	0.049	2765	26	2793	61	2745	10	42.984	2.305
608-18	0.660	0.065	16.911	1.829	0.192	0.002	1.804	0.100	2794	53	2843	127	2759	15	23.321	1.643
608-19	0.588	0.035	15.356	0.924	0.191	0.002	1.832	0.081	2773	43	2807	100	2748	15	29.169	1.694
608-20	0.560	0.021	14.602	0.575	0.189	0.001	1.868	0.061	2747	32	2764	73	2733	12	45.473	3.694
608-21	0.572	0.027	14.886	0.600	0.193	0.001	1.894	0.061	2755	31	2733	71	2770	12	40.998	2.941
608-22	0.569	0.088	14.920	2.356	0.192	0.002	1.856	0.108	2765	56	2779	131	2756	19	19.954	1.543
608-23	0.616	0.039	15.991	0.947	0.191	0.002	1.799	0.079	2793	43	2849	101	2753	15	26.438	1.583
608-24	0.522	0.014	13.647	0.357	0.192	0.001	1.922	0.048	2732	25	2701	56	2755	10	52.696	2.150
608-25	0.589	0.026	15.558	0.709	0.192	0.002	1.780	0.069	2805	38	2874	90	2755	16	30.420	1.767
608-26	0.644	0.053	17.092	1.554	0.188	0.002	1.796	0.108	2780	58	2854	139	2728	16	21.737	1.561
608-27	0.607	0.030	15.935	0.775	0.190	0.002	1.700	0.077	2842	44	2982	109	2744	16	31.496	1.793
608-28	0.540	0.013	13.992	0.338	0.189	0.001	1.865	0.041	2748	22	2768	50	2733	9	57.385	2.448
608-29	0.607	0.010	15.707	0.254	0.188	0.001	1.655	0.028	2857	17	3047	42	2726	9	78.571	2.441
608-30	0.529	0.018	13.456	0.445	0.188	0.001	1.935	0.067	2708	34	2686	77	2724	12	39.067	2.146
608-31	0.607	0.051	15.714	1.334	0.187	0.001	1.872	0.079	2736	41	2759	95	2720	13	29.339	1.608
	611 (strongly altered)															

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
611-1	0.531	0.004	13.729	0.105	0.188	0.000	1.887	0.013	2732	7	2742	16	2724	4	116.426	1.592
611-2	0.524	0.005	13.581	0.132	0.188	0.001	1.906	0.017	2722	9	2719	20	2725	5	51.444	1.268
611-3	0.531	0.005	13.760	0.122	0.189	0.000	1.883	0.017	2736	9	2746	20	2729	4	112.934	5.723
611-4	0.521	0.005	13.765	0.133	0.192	0.001	1.923	0.018	2734	10	2699	21	2760	6	57.062	4.127
611-5	0.528	0.007	14.058	0.189	0.193	0.001	1.891	0.023	2752	12	2737	27	2764	5	238.410	13.464
611-6	0.512	0.011	13.492	0.286	0.191	0.001	1.955	0.037	2711	19	2664	41	2746	9	90.134	7.435
611-7	0.531	0.007	13.995	0.175	0.190	0.001	1.876	0.022	2748	12	2754	27	2744	7	193.361	13.327
611-8	0.523	0.011	13.974	0.294	0.191	0.001	1.919	0.039	2732	20	2703	45	2753	9	94.679	7.974
611-9	0.579	0.008	15.342	0.226	0.191	0.001	1.719	0.025	2836	14	2955	34	2752	6	138.514	6.310
611-10	0.542	0.005	14.338	0.152	0.190	0.001	1.829	0.018	2771	10	2811	22	2742	6	146.471	4.486
611-11	0.549	0.018	14.057	0.451	0.187	0.001	1.869	0.042	2733	22	2762	50	2712	10	59.452	4.446
611-12	0.565	0.010	14.339	0.277	0.185	0.001	1.768	0.035	2776	19	2890	46	2695	7	86.682	3.390
611-13	0.544	0.018	13.921	0.475	0.187	0.001	1.894	0.063	2724	32	2733	74	2717	12	39.594	1.669
611-14	0.530	0.006	13.666	0.171	0.187	0.001	1.891	0.023	2726	12	2736	27	2718	6	139.342	6.270
611-15	0.534	0.007	13.782	0.168	0.188	0.001	1.874	0.025	2737	13	2757	30	2723	6	137.704	5.820
611-16*	0.495	0.009	12.961	0.255	0.191	0.001	2.014	0.036	2684	18	2599	38	2748	9	96.421	5.682
611-17	0.527	0.015	13.435	0.387	0.186	0.001	1.941	0.052	2695	26	2679	59	2707	11	47.980	2.179
611-18	0.562	0.010	14.445	0.282	0.187	0.001	1.795	0.030	2772	17	2854	39	2712	8	87.126	7.009
611-19*	0.506	0.008	13.050	0.209	0.190	0.001	1.978	0.032	2694	16	2637	35	2737	9	83.162	4.077
611-20	0.568	0.010	14.570	0.273	0.187	0.001	1.760	0.032	2792	18	2900	43	2715	10	66.755	2.727
611-21	0.532	0.008	13.565	0.203	0.185	0.001	1.885	0.028	2718	15	2744	33	2699	8	117.967	7.751
611-22	0.550	0.011	14.004	0.272	0.185	0.001	1.836	0.036	2743	19	2803	44	2700	9	66.842	2.716
611-23	0.560	0.014	14.160	0.361	0.184	0.001	1.795	0.044	2757	24	2854	56	2686	11	52.141	4.349
611-24	0.538	0.009	13.655	0.229	0.184	0.001	1.862	0.030	2725	16	2771	37	2692	9	75.071	1.830
611-25	0.542	0.014	13.833	0.360	0.186	0.001	1.856	0.042	2738	23	2778	51	2708	13	62.780	3.524
611-26*	0.609	0.012	15.542	0.329	0.184	0.001	1.657	0.034	2836	20	3044	49	2692	6	139.384	9.587
611-27	0.560	0.006	14.356	0.157	0.186	0.001	1.794	0.019	2768	11	2856	24	2704	6	192.227	16.463
611-28	0.551	0.007	14.079	0.184	0.185	0.001	1.820	0.021	2751	12	2823	27	2698	7	130.870	7.977

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
611-29	0.513	0.006	13.241	0.165	0.187	0.001	1.954	0.023	2692	12	2665	26	2712	7	109.209	3.794
611-30*	0.579	0.009	15.113	0.261	0.188	0.001	1.715	0.028	2824	16	2961	39	2727	8	95.509	1.526
611-31	0.536	0.009	13.971	0.244	0.188	0.001	1.852	0.030	2750	16	2783	37	2726	9	74.982	3.262
	612 (weakly altered)															
612-1	0.535	0.005	14.117	0.168	0.191	0.001	1.871	0.019	2753	11	2760	23	2747	9	161.517	3.339
612-2	0.537	0.006	14.029	0.150	0.189	0.001	1.863	0.018	2750	10	2769	22	2735	6	38.717	1.052
612-3	0.544	0.005	14.412	0.121	0.192	0.001	1.839	0.017	2776	10	2799	21	2759	7	86.696	5.722
612-4	0.537	0.005	14.082	0.119	0.190	0.001	1.861	0.015	2754	8	2773	18	2740	5	57.973	1.536
612-5	0.528	0.004	13.874	0.161	0.190	0.001	1.895	0.015	2739	10	2731	18	2745	11	73.772	3.534
612-6	0.574	0.009	14.920	0.254	0.188	0.001	1.751	0.028	2804	16	2912	37	2728	8	56.961	4.068
612-7	0.536	0.003	14.073	0.083	0.191	0.000	1.865	0.011	2756	6	2768	13	2747	4	104.051	2.198
612-8	0.550	0.005	14.488	0.154	0.191	0.001	1.816	0.018	2782	11	2829	23	2748	10	93.010	1.227
612-9	0.568	0.007	15.013	0.182	0.192	0.001	1.765	0.021	2814	12	2894	28	2757	6	72.686	1.811
612-10	0.561	0.006	14.729	0.174	0.190	0.000	1.787	0.020	2795	11	2865	26	2746	4	82.665	1.632
612-11	0.567	0.008	15.023	0.205	0.192	0.001	1.773	0.022	2809	13	2884	29	2755	8	66.285	2.524
612-12	0.526	0.003	13.838	0.095	0.191	0.000	1.899	0.012	2739	7	2727	15	2748	4	125.849	3.449
612-13	0.567	0.004	14.826	0.102	0.190	0.001	1.762	0.012	2805	7	2897	15	2739	4	87.524	1.362
612-14	0.533	0.003	13.980	0.093	0.190	0.000	1.875	0.012	2749	6	2756	14	2745	3	194.422	3.802
612-15	0.535	0.004	13.995	0.102	0.190	0.000	1.873	0.012	2748	7	2758	15	2741	4	90.640	1.690
612-16	0.542	0.006	14.177	0.156	0.190	0.001	1.852	0.019	2758	10	2783	23	2739	6	36.708	0.956
612-17	0.541	0.005	14.197	0.141	0.190	0.001	1.853	0.019	2760	10	2781	23	2745	6	46.649	1.164
612-18	0.543	0.007	14.334	0.194	0.191	0.001	1.848	0.024	2768	13	2788	29	2753	8	31.377	0.938
612-19	0.551	0.005	14.443	0.130	0.190	0.001	1.821	0.016	2776	9	2822	20	2743	5	51.522	2.490
612-20	0.555	0.004	14.668	0.103	0.192	0.001	1.804	0.013	2793	8	2843	16	2757	6	83.715	1.592
612-21	0.530	0.004	14.007	0.126	0.192	0.001	1.883	0.016	2751	9	2746	19	2755	6	83.762	1.528
612-22	0.544	0.008	14.405	0.180	0.192	0.001	1.838	0.025	2775	14	2800	31	2756	7	79.744	4.186
612-23	0.562	0.006	14.967	0.178	0.193	0.001	1.781	0.018	2811	12	2873	23	2766	11	113.644	3.088
612-24*	0.507	0.005	13.396	0.146	0.191	0.000	1.965	0.021	2706	10	2652	23	2746	3	492.243	26.751

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
612-25	0.541	0.009	14.206	0.243	0.190	0.001	1.845	0.030	2762	16	2792	36	2740	8	85.701	4.032
612-26	0.558	0.010	14.710	0.259	0.190	0.001	1.789	0.031	2794	17	2862	40	2744	8	79.264	3.477
612-27*	0.481	0.006	12.674	0.169	0.191	0.001	2.064	0.027	2661	13	2546	28	2750	6	169.794	8.558
612-28	0.540	0.007	14.193	0.208	0.189	0.001	1.844	0.023	2761	12	2793	28	2737	7	130.485	6.989
612-29	0.543	0.006	14.295	0.168	0.190	0.001	1.836	0.021	2770	11	2804	26	2745	6	188.417	6.988
612-30	0.562	0.014	14.750	0.374	0.190	0.001	1.787	0.044	2792	24	2865	57	2740	11	51.055	2.533
612-31	0.552	0.009	14.497	0.239	0.189	0.001	1.825	0.029	2766	16	2816	36	2730	8	91.205	4.850
612-32	0.548	0.009	14.276	0.245	0.187	0.001	1.831	0.028	2753	15	2809	35	2712	8	91.297	5.055
612-33	0.545	0.014	14.130	0.362	0.187	0.001	1.879	0.045	2731	23	2751	53	2716	10	55.314	2.756
612-34	0.558	0.017	14.336	0.421	0.187	0.001	1.812	0.054	2767	29	2833	68	2719	11	41.217	1.361
612-35	0.581	0.013	15.112	0.352	0.188	0.001	1.744	0.037	2804	20	2922	49	2720	8	83.974	6.173
612-36	0.565	0.008	14.741	0.209	0.187	0.001	1.775	0.025	2787	14	2881	33	2719	7	108.603	4.717
612-37	0.550	0.011	14.366	0.312	0.187	0.001	1.833	0.034	2755	19	2807	43	2718	10	64.395	2.263
612-38	0.562	0.018	14.420	0.455	0.185	0.001	1.816	0.057	2754	30	2828	72	2700	10	41.149	2.030
612-39	0.540	0.009	13.963	0.236	0.185	0.001	1.859	0.030	2731	16	2775	37	2699	7	123.727	6.896
612-40	0.559	0.014	14.461	0.343	0.188	0.001	1.796	0.044	2781	24	2854	56	2728	12	51.998	1.640
612-41	0.577	0.023	14.838	0.590	0.185	0.001	1.821	0.058	2751	31	2821	73	2700	10	41.553	1.591
612-42	0.540	0.011	14.110	0.301	0.188	0.001	1.867	0.036	2742	19	2766	43	2724	10	62.575	2.794
612-43	0.537	0.015	13.957	0.420	0.187	0.001	1.866	0.048	2735	25	2767	58	2711	11	62.866	5.641
612-44	0.642	0.041	16.916	1.183	0.188	0.001	1.733	0.071	2812	39	2937	96	2724	11	35.074	1.927
612-45	0.532	0.008	13.879	0.207	0.188	0.001	1.871	0.028	2740	15	2760	33	2725	7	112.825	5.310
612-46	0.540	0.007	13.947	0.161	0.187	0.001	1.854	0.023	2743	12	2781	28	2716	6	163.755	11.506
612-47	0.541	0.007	14.098	0.198	0.188	0.001	1.846	0.023	2752	12	2791	28	2724	6	128.171	7.516
612-48	0.528	0.007	13.739	0.186	0.188	0.000	1.892	0.024	2726	12	2736	28	2720	4	721.755	20.295
612-49	0.539	0.007	13.955	0.184	0.189	0.001	1.850	0.022	2757	12	2786	27	2737	6	190.985	12.736
612-50	0.541	0.011	14.080	0.281	0.190	0.001	1.853	0.034	2761	18	2782	41	2745	8	88.762	5.390
	613 (moderately altered)															
613-1	0.540	0.005	14.206	0.135	0.191	0.001	1.853	0.018	2763	10	2782	22	2750	6	55.074	2.099

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
613-2	0.524	0.004	13.833	0.105	0.192	0.001	1.909	0.013	2738	7	2715	15	2755	5	94.060	1.541
613-3	0.530	0.004	14.001	0.101	0.191	0.000	1.886	0.013	2748	7	2742	16	2753	4	99.031	4.723
613-4	0.538	0.004	14.133	0.101	0.191	0.001	1.859	0.013	2759	7	2775	16	2747	5	62.673	1.855
613-5	0.523	0.004	13.717	0.105	0.189	0.000	1.911	0.014	2726	7	2713	16	2736	4	96.035	4.331
613-6	0.537	0.006	14.106	0.171	0.190	0.001	1.868	0.021	2749	11	2764	26	2738	6	46.463	2.546
613-7	0.532	0.005	13.948	0.142	0.189	0.001	1.881	0.018	2741	10	2749	22	2736	5	69.781	5.421
613-8	0.539	0.005	14.207	0.135	0.190	0.001	1.854	0.017	2757	9	2781	21	2740	5	61.997	2.942
613-9	0.527	0.006	13.834	0.164	0.189	0.001	1.902	0.021	2731	11	2724	25	2736	6	40.976	1.750
613-10	0.537	0.003	14.143	0.092	0.190	0.000	1.860	0.012	2755	7	2774	15	2740	4	120.346	2.812
613-11	0.525	0.006	13.844	0.167	0.191	0.001	1.906	0.021	2736	11	2719	25	2748	7	46.348	1.169
613-12	0.545	0.006	14.223	0.155	0.189	0.001	1.839	0.020	2763	11	2799	25	2736	6	57.329	2.615
613-13	0.529	0.007	14.010	0.186	0.192	0.001	1.885	0.023	2752	12	2743	27	2758	8	47.586	2.228
613-14	0.525	0.003	13.762	0.085	0.190	0.000	1.903	0.012	2735	6	2722	14	2745	3	206.634	7.364
613-15	0.526	0.005	13.765	0.141	0.190	0.001	1.903	0.018	2733	10	2722	21	2741	6	54.525	0.564
613-16	0.521	0.005	13.667	0.133	0.190	0.001	1.910	0.018	2728	9	2714	21	2738	5	78.095	3.571
613-17	0.532	0.008	13.893	0.213	0.189	0.001	1.884	0.027	2739	14	2745	32	2735	9	33.170	1.102
613-18	0.540	0.007	14.130	0.194	0.190	0.001	1.862	0.024	2753	13	2771	29	2740	8	27.852	0.850
613-19	0.532	0.004	13.902	0.106	0.190	0.001	1.881	0.014	2743	7	2748	16	2739	4	80.772	2.711
613-20	0.547	0.004	14.325	0.118	0.190	0.001	1.828	0.014	2771	8	2813	17	2740	4	81.335	1.633
613-21	0.550	0.005	14.413	0.141	0.190	0.001	1.818	0.017	2776	10	2826	22	2741	6	43.545	1.397
613-22	0.527	0.004	13.813	0.122	0.190	0.001	1.896	0.016	2737	8	2730	18	2742	5	68.646	1.009
613-23	0.525	0.004	13.761	0.119	0.190	0.001	1.905	0.016	2733	8	2720	18	2743	5	58.569	0.803
613-24	0.528	0.006	13.827	0.179	0.190	0.001	1.898	0.023	2735	12	2728	27	2739	7	31.937	0.892
613-25	0.520	0.005	13.630	0.126	0.190	0.001	1.924	0.017	2724	9	2699	19	2743	5	55.447	0.522
613-26	0.530	0.007	13.839	0.203	0.189	0.001	1.892	0.025	2736	13	2736	30	2736	8	27.771	0.807
613-27	0.522	0.005	13.632	0.134	0.190	0.001	1.921	0.018	2725	10	2702	21	2742	6	61.735	3.487
613-28	0.532	0.006	13.924	0.180	0.190	0.001	1.887	0.022	2740	12	2742	26	2739	7	34.465	1.294
613-29	0.524	0.005	13.734	0.147	0.190	0.001	1.911	0.020	2731	10	2713	23	2744	6	48.183	1.922

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
613-30	0.536	0.007	14.056	0.214	0.190	0.001	1.862	0.027	2752	14	2771	33	2739	7	33.264	1.806
613-31	0.529	0.005	13.917	0.134	0.191	0.001	1.892	0.017	2743	9	2735	20	2749	6	50.325	1.674
613-32	0.531	0.004	13.948	0.111	0.191	0.000	1.882	0.014	2747	7	2747	16	2746	4	142.938	6.319
613-33	0.524	0.005	13.746	0.133	0.190	0.001	1.904	0.018	2732	9	2721	21	2741	6	52.594	2.574
613-34	0.529	0.004	13.951	0.115	0.192	0.001	1.891	0.014	2747	8	2737	17	2755	5	104.350	3.879
613-35	0.537	0.006	14.041	0.145	0.189	0.001	1.867	0.019	2749	10	2765	23	2737	5	62.653	3.074
613-36	0.527	0.006	13.749	0.163	0.189	0.001	1.898	0.021	2731	11	2728	24	2733	6	50.001	5.221
613-37	0.545	0.004	14.277	0.106	0.189	0.001	1.835	0.014	2765	8	2805	17	2736	5	83.892	1.335
613-38	0.540	0.005	14.149	0.122	0.190	0.001	1.853	0.016	2758	9	2782	19	2741	5	74.060	3.692
613-39	0.532	0.005	13.847	0.141	0.189	0.001	1.884	0.019	2737	10	2745	22	2730	6	49.922	1.205
613-40	0.536	0.005	14.009	0.125	0.189	0.001	1.865	0.016	2749	9	2767	20	2735	5	57.010	1.868
613-41	0.524	0.005	13.675	0.149	0.189	0.001	1.912	0.019	2723	10	2712	22	2731	6	49.177	1.655
613-42	0.516	0.010	13.448	0.271	0.189	0.001	1.942	0.036	2709	18	2678	40	2733	8	90.343	2.744
613-43	0.541	0.015	14.025	0.397	0.188	0.001	1.868	0.052	2743	27	2764	62	2727	9	68.425	6.463
613-44	0.528	0.010	14.069	0.282	0.193	0.001	1.912	0.037	2744	19	2712	42	2768	8	81.022	2.354
613-45	0.522	0.011	13.857	0.287	0.193	0.001	1.926	0.040	2737	21	2696	46	2768	10	53.418	1.851
613-46	0.526	0.010	13.970	0.258	0.193	0.001	1.911	0.036	2742	18	2713	42	2763	7	102.910	6.593
613-47	0.531	0.014	14.048	0.386	0.192	0.001	1.912	0.052	2739	26	2712	60	2759	9	55.467	2.384
613-48	0.530	0.010	14.124	0.286	0.193	0.001	1.902	0.037	2749	19	2724	44	2768	7	96.207	5.799
613-49	0.536	0.010	14.319	0.291	0.193	0.001	1.879	0.036	2763	19	2751	43	2771	9	85.591	3.905
613-50	0.547	0.017	14.371	0.446	0.191	0.001	1.872	0.057	2753	30	2760	68	2747	11	41.944	1.589
613-51	0.532	0.008	14.159	0.215	0.192	0.001	1.881	0.027	2756	14	2749	32	2762	6	117.270	6.922
613-52	0.551	0.018	14.109	0.419	0.189	0.001	1.856	0.054	2751	28	2778	66	2731	11	49.106	1.972
613-53	0.533	0.019	13.878	0.496	0.190	0.001	1.902	0.058	2736	30	2724	68	2744	10	79.837	10.217
613-54	0.529	0.011	13.739	0.283	0.190	0.001	1.889	0.037	2739	19	2739	44	2740	8	87.161	4.756
613-55	0.533	0.009	13.868	0.252	0.189	0.001	1.870	0.033	2747	17	2761	39	2737	7	116.929	6.061
613-56	0.526	0.009	13.626	0.251	0.189	0.001	1.896	0.033	2734	17	2731	39	2736	8	104.070	7.781
613-57	0.524	0.010	13.513	0.260	0.189	0.001	1.911	0.038	2723	19	2713	44	2731	8	85.987	2.507

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
613-58	0.529	0.007	13.687	0.192	0.189	0.001	1.882	0.025	2737	13	2748	29	2730	6	147.985	5.584
613-59	0.556	0.012	14.378	0.303	0.189	0.001	1.806	0.039	2777	21	2841	50	2731	8	71.242	1.674
613-60	0.508	0.006	13.100	0.168	0.188	0.001	1.960	0.024	2697	12	2657	26	2726	5	283.288	25.367
613-61*	0.557	0.014	14.733	0.403	0.191	0.001	1.793	0.048	2795	26	2857	62	2751	10	56.906	4.315
613-62	0.538	0.012	14.168	0.339	0.190	0.001	1.858	0.043	2758	22	2776	52	2745	9	67.894	4.881
613-63	0.539	0.016	14.208	0.430	0.191	0.001	1.866	0.057	2756	30	2767	69	2747	12	43.811	2.478
613-64	0.551	0.011	14.422	0.302	0.190	0.001	1.814	0.037	2777	20	2830	47	2738	9	68.379	2.867
613-65*	0.566	0.026	15.000	0.755	0.190	0.001	1.836	0.071	2766	37	2803	88	2740	13	43.751	3.284
613-66	0.520	0.012	13.592	0.309	0.190	0.001	1.919	0.045	2726	23	2703	52	2743	9	80.752	5.531
613-67	0.545	0.010	14.403	0.283	0.191	0.000	1.820	0.033	2781	18	2823	42	2750	4	434.823	34.807
613-68	0.521	0.007	13.603	0.179	0.189	0.001	1.899	0.025	2732	13	2727	29	2736	6	146.228	5.705
613-69	0.549	0.012	14.483	0.330	0.191	0.001	1.818	0.039	2781	21	2826	49	2749	9	63.464	2.586
613-70	0.531	0.014	13.981	0.372	0.191	0.001	1.894	0.050	2741	26	2733	59	2746	10	53.839	2.828
613-71	0.533	0.010	13.869	0.280	0.188	0.001	1.869	0.038	2741	20	2762	46	2726	9	74.845	1.384
613-72*	0.567	0.009	14.678	0.242	0.187	0.001	1.758	0.028	2796	16	2904	38	2718	7	121.423	6.699
613-73	0.520	0.008	13.521	0.222	0.188	0.001	1.906	0.033	2722	17	2718	38	2725	7	119.227	7.474
613-74	0.524	0.008	13.611	0.220	0.188	0.001	1.891	0.030	2727	16	2736	35	2720	8	129.431	12.611
613-75	0.529	0.012	13.669	0.324	0.187	0.001	1.864	0.048	2735	25	2768	57	2711	9	75.789	4.661
613-76	0.540	0.014	13.931	0.373	0.187	0.001	1.858	0.047	2739	25	2776	57	2711	12	52.601	2.328
613-77	0.529	0.011	13.667	0.292	0.187	0.001	1.891	0.041	2722	21	2737	48	2712	9	80.386	3.418
613-78	0.529	0.008	13.726	0.231	0.188	0.001	1.882	0.029	2732	16	2747	35	2721	9	83.282	2.045
613-79	0.526	0.011	13.622	0.318	0.187	0.001	1.891	0.041	2723	21	2737	48	2713	9	69.774	2.967
613-80	0.542	0.011	14.060	0.300	0.188	0.001	1.829	0.036	2759	19	2812	45	2721	10	68.616	3.216
613-81	0.555	0.015	14.419	0.406	0.188	0.001	1.829	0.048	2764	25	2812	59	2728	9	63.232	3.748
613-82	0.538	0.014	13.966	0.371	0.188	0.001	1.865	0.050	2745	26	2767	61	2728	11	65.190	4.211
613-83	0.574	0.032	14.925	0.832	0.189	0.001	1.843	0.061	2757	32	2794	75	2731	12	48.616	3.985
613-84	0.547	0.016	14.093	0.414	0.187	0.001	1.832	0.054	2755	28	2808	67	2716	10	56.296	3.402
613-85	0.548	0.014	14.235	0.368	0.189	0.001	1.839	0.046	2758	25	2800	57	2728	10	61.776	2.770

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
613-86	0.551	0.019	14.190	0.463	0.189	0.001	1.835	0.059	2763	31	2804	72	2734	10	50.192	3.083
613-87*	0.506	0.007	13.175	0.201	0.189	0.001	1.966	0.028	2696	14	2651	31	2730	7	148.402	10.909
613-88	0.533	0.013	13.773	0.329	0.188	0.001	1.880	0.042	2733	22	2750	50	2721	10	68.287	4.961
613-89*	0.563	0.013	14.772	0.345	0.190	0.001	1.780	0.041	2798	23	2875	54	2743	9	81.907	9.418
613-90	0.543	0.014	14.235	0.364	0.190	0.001	1.864	0.047	2755	25	2769	57	2745	10	57.881	1.824
613-91	0.545	0.014	14.268	0.351	0.190	0.001	1.851	0.043	2758	23	2785	52	2739	9	57.942	2.648
613-92	0.542	0.016	14.229	0.454	0.190	0.001	1.886	0.056	2741	29	2742	66	2740	10	53.607	2.706
613-93	0.526	0.011	13.791	0.292	0.190	0.001	1.898	0.043	2736	22	2729	50	2741	9	71.531	4.156
613-94	0.539	0.016	14.229	0.441	0.190	0.001	1.864	0.053	2755	28	2769	64	2744	9	90.308	7.684
613-95	0.530	0.010	13.918	0.278	0.190	0.001	1.873	0.034	2746	18	2758	41	2737	9	93.165	5.960
	614 (strongly altered)															
614-1*	0.466	0.005	12.115	0.132	0.189	0.000	2.150	0.023	2613	10	2462	22	2732	4	90.760	2.770
614-2	0.525	0.004	13.741	0.112	0.190	0.001	1.905	0.015	2733	8	2720	17	2742	5	102.888	0.696
614-3	0.537	0.013	13.928	0.326	0.187	0.001	1.884	0.042	2730	21	2745	49	2720	9	48.614	2.739
614-4	0.546	0.008	14.128	0.222	0.187	0.001	1.833	0.026	2752	14	2806	32	2713	6	99.907	6.395
614-5	0.538	0.010	13.952	0.258	0.187	0.001	1.856	0.033	2742	17	2778	40	2715	8	76.439	3.546
614-6*	0.630	0.011	16.363	0.305	0.187	0.001	1.585	0.028	2893	17	3152	45	2717	5	165.451	9.085
614-7	0.543	0.006	14.178	0.157	0.189	0.000	1.842	0.020	2758	10	2796	24	2730	4	542.013	35.918
614-8	0.543	0.006	14.065	0.166	0.188	0.001	1.844	0.021	2751	11	2793	26	2721	6	178.976	10.991
614-9	0.535	0.005	13.922	0.131	0.188	0.001	1.870	0.016	2742	9	2761	19	2728	4	264.594	13.778
614-10	0.529	0.007	13.607	0.172	0.188	0.001	1.896	0.023	2727	12	2730	27	2725	6	174.694	7.668
614-11	0.550	0.016	14.084	0.424	0.187	0.001	1.869	0.050	2735	26	2762	60	2715	9	48.993	3.227
614-12	0.564	0.020	14.567	0.529	0.187	0.001	1.844	0.057	2750	30	2793	70	2718	11	42.608	2.731
614-13	0.541	0.010	13.955	0.264	0.188	0.001	1.848	0.033	2751	18	2788	41	2724	9	69.453	2.174
614-14	0.539	0.010	13.939	0.290	0.188	0.001	1.869	0.035	2742	19	2762	43	2727	10	55.515	2.282
614-15	0.537	0.008	13.850	0.218	0.188	0.001	1.869	0.028	2741	14	2763	33	2725	6	149.502	12.663
614-16	0.538	0.006	13.868	0.159	0.188	0.001	1.863	0.021	2744	11	2770	25	2725	6	201.555	16.234
614-17	0.528	0.008	13.622	0.205	0.189	0.001	1.898	0.026	2729	13	2728	30	2730	6	325.241	39.199

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
614-18	0.536	0.008	13.701	0.212	0.188	0.001	1.876	0.028	2737	15	2754	34	2725	7	108.745	7.765
614-19	0.575	0.010	14.792	0.258	0.188	0.001	1.753	0.031	2801	17	2910	41	2723	7	79.804	3.377
614-20	0.548	0.006	14.103	0.146	0.188	0.001	1.823	0.019	2764	10	2819	23	2723	5	258.706	18.615
614-21	0.537	0.011	13.813	0.279	0.187	0.001	1.862	0.034	2738	18	2772	41	2713	10	66.740	2.191
614-22	0.543	0.006	13.970	0.167	0.187	0.001	1.842	0.021	2751	11	2795	26	2719	5	152.970	9.986
614-23	0.549	0.011	14.113	0.300	0.187	0.001	1.826	0.037	2758	20	2816	46	2715	10	57.091	1.598
614-24	0.544	0.010	13.894	0.251	0.187	0.001	1.833	0.032	2754	17	2807	40	2716	7	115.900	13.141
614-25	0.539	0.010	13.814	0.255	0.187	0.001	1.866	0.032	2739	17	2767	38	2719	8	97.460	5.948
614-26	0.544	0.014	14.043	0.393	0.187	0.001	1.852	0.047	2745	25	2783	57	2717	9	49.789	2.288
614-27	0.541	0.012	13.925	0.312	0.188	0.001	1.856	0.038	2745	20	2778	46	2721	10	68.138	4.309
614-28	0.551	0.014	14.142	0.355	0.187	0.001	1.814	0.045	2764	24	2831	57	2716	10	57.468	2.825
614-29	0.526	0.006	13.543	0.158	0.188	0.001	1.897	0.022	2724	11	2730	26	2720	5	225.764	8.304
614-30	0.539	0.012	14.091	0.317	0.191	0.001	1.859	0.039	2759	21	2775	48	2747	10	64.180	3.909
614-31	0.551	0.016	14.400	0.458	0.191	0.001	1.851	0.051	2763	27	2785	62	2747	11	45.706	2.112
	615 (least altered)															
615-1	0.535	0.008	13.891	0.206	0.189	0.001	1.874	0.027	2742	14	2756	32	2731	8	26.163	0.875
615-2	0.532	0.007	14.092	0.196	0.192	0.001	1.889	0.024	2749	13	2739	29	2756	8	32.187	1.018
615-3	0.531	0.004	13.925	0.102	0.190	0.000	1.883	0.013	2743	7	2746	16	2741	4	75.813	2.615
615-4	0.538	0.003	14.098	0.087	0.190	0.000	1.856	0.010	2755	6	2778	13	2739	4	87.453	2.241
615-5	0.543	0.007	14.277	0.176	0.190	0.001	1.844	0.023	2765	12	2793	28	2745	6	39.684	1.711
615-6	0.527	0.004	13.798	0.115	0.190	0.001	1.896	0.015	2735	8	2731	17	2737	5	54.715	2.372
615-7	0.527	0.006	13.822	0.152	0.190	0.001	1.896	0.021	2738	11	2730	25	2744	7	39.706	2.231
615-8	0.532	0.004	13.937	0.109	0.190	0.001	1.879	0.014	2745	7	2751	16	2741	4	72.219	1.505
615-9	0.528	0.004	13.873	0.101	0.191	0.001	1.896	0.013	2741	7	2731	15	2748	5	66.502	2.177
615-10	0.538	0.006	14.305	0.179	0.193	0.001	1.863	0.022	2767	12	2770	27	2765	7	44.403	1.030
615-11	0.535	0.006	14.107	0.185	0.191	0.001	1.874	0.024	2755	13	2757	28	2753	7	30.240	0.954
615-12	0.533	0.003	14.048	0.073	0.191	0.000	1.877	0.010	2754	5	2753	12	2754	4	139.050	3.681
615-13	0.531	0.003	14.038	0.087	0.192	0.000	1.881	0.011	2752	6	2749	13	2755	4	99.168	2.780

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
615-14	0.558	0.005	14.757	0.117	0.192	0.000	1.795	0.014	2800	8	2855	18	2761	3	153.028	4.981
615-15	0.526	0.003	13.894	0.081	0.192	0.000	1.900	0.010	2744	6	2726	12	2757	4	95.275	3.120
615-16	0.532	0.003	14.051	0.087	0.192	0.001	1.879	0.011	2755	6	2751	14	2758	4	82.130	1.975
615-17	0.537	0.005	14.178	0.161	0.191	0.001	1.865	0.018	2759	10	2768	22	2752	7	38.113	0.624
615-18	0.547	0.015	14.260	0.392	0.189	0.001	1.870	0.049	2745	25	2762	59	2733	10	11.887	0.376
615-19	0.545	0.007	14.324	0.187	0.191	0.001	1.837	0.025	2772	13	2802	31	2751	7	100.753	19.404
615-20	0.541	0.005	14.072	0.128	0.189	0.001	1.852	0.017	2754	9	2784	21	2732	6	38.208	1.395
615-21	0.533	0.006	13.844	0.155	0.188	0.001	1.881	0.020	2737	11	2748	24	2728	7	31.579	0.969
615-22	0.520	0.003	13.785	0.100	0.192	0.001	1.923	0.012	2734	7	2699	14	2759	4	85.443	2.756
615-23	0.530	0.003	13.839	0.095	0.189	0.000	1.886	0.013	2739	7	2742	15	2736	4	64.753	1.801
615-24	0.536	0.006	14.175	0.170	0.192	0.001	1.871	0.021	2758	12	2761	26	2757	10	32.982	0.835
615-25	0.534	0.010	14.097	0.262	0.191	0.001	1.888	0.034	2748	18	2740	40	2753	9	17.379	0.596
615-26	0.529	0.005	13.766	0.140	0.189	0.001	1.895	0.018	2731	10	2731	21	2731	5	69.184	5.759
615-27	0.527	0.004	13.780	0.098	0.190	0.001	1.901	0.013	2733	7	2725	15	2739	5	56.892	1.706
615-28	0.560	0.008	14.665	0.215	0.190	0.001	1.801	0.025	2786	14	2847	32	2742	7	29.621	0.850
615-29	0.524	0.003	13.804	0.080	0.191	0.000	1.910	0.010	2735	5	2714	12	2750	3	151.939	3.905
615-30	0.529	0.004	13.884	0.105	0.190	0.001	1.895	0.013	2740	7	2732	16	2745	4	74.586	2.677
615-31	0.525	0.003	13.774	0.085	0.190	0.001	1.906	0.012	2733	6	2719	13	2744	5	74.671	2.389
615-32	0.516	0.003	13.546	0.067	0.190	0.000	1.939	0.009	2717	5	2681	11	2744	4	125.146	4.204
615-33	0.539	0.005	14.318	0.151	0.192	0.001	1.855	0.018	2769	10	2780	22	2761	7	47.659	2.812
615-34	0.534	0.005	14.039	0.146	0.191	0.001	1.878	0.019	2749	10	2751	22	2748	6	43.457	1.647
615-35	0.554	0.005	14.535	0.125	0.190	0.000	1.812	0.016	2782	9	2833	20	2744	4	111.536	6.363
615-36	0.521	0.004	13.695	0.110	0.191	0.001	1.923	0.015	2726	8	2699	17	2746	5	60.528	2.142
615-37	0.524	0.003	13.859	0.101	0.192	0.001	1.909	0.012	2741	7	2715	14	2761	5	114.878	0.888
615-38	0.537	0.003	14.128	0.089	0.191	0.001	1.863	0.011	2760	6	2770	13	2752	4	169.925	4.685
615-39	0.553	0.004	14.523	0.096	0.191	0.001	1.809	0.012	2786	7	2837	15	2749	4	76.731	2.343
615-40	0.538	0.008	14.147	0.211	0.191	0.001	1.873	0.027	2752	15	2758	32	2748	9	26.306	0.599
615-41	0.546	0.006	14.315	0.146	0.190	0.000	1.833	0.019	2769	10	2806	24	2742	4	103.237	6.947

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
615-42	0.536	0.004	14.057	0.118	0.190	0.001	1.867	0.015	2753	8	2765	18	2745	5	61.798	1.765
615-43	0.537	0.004	13.995	0.093	0.190	0.000	1.865	0.014	2751	7	2768	17	2738	4	88.561	3.685
615-44	0.543	0.007	14.196	0.188	0.190	0.001	1.850	0.022	2760	12	2786	27	2742	7	35.249	1.594
615-45	0.545	0.005	14.274	0.126	0.190	0.001	1.836	0.016	2767	9	2804	20	2741	5	73.889	2.066
615-46	0.525	0.002	13.743	0.067	0.190	0.000	1.905	0.009	2734	5	2720	10	2744	4	124.598	5.221
615-47	0.541	0.004	14.318	0.103	0.192	0.001	1.847	0.013	2769	7	2789	16	2755	5	62.225	1.485
615-48	0.531	0.007	13.891	0.182	0.190	0.001	1.888	0.026	2740	14	2741	30	2740	7	29.260	1.014
615-49	0.534	0.004	14.055	0.109	0.191	0.001	1.872	0.014	2751	8	2759	17	2746	5	52.439	2.288
615-50	0.536	0.004	14.163	0.127	0.191	0.001	1.867	0.016	2758	9	2765	19	2752	7	47.809	1.454
615-51	0.544	0.009	14.304	0.254	0.190	0.001	1.845	0.031	2765	17	2792	38	2744	9	24.829	0.824
615-52	0.525	0.007	13.795	0.181	0.190	0.001	1.910	0.023	2732	12	2715	27	2744	8	30.069	0.854
615-53	0.534	0.005	13.923	0.152	0.189	0.001	1.875	0.019	2743	10	2755	22	2733	5	34.834	0.880
615-54	0.532	0.006	13.894	0.151	0.190	0.001	1.886	0.020	2740	10	2743	23	2737	6	32.823	0.670
615-55	0.539	0.004	14.091	0.120	0.190	0.001	1.856	0.015	2755	8	2778	18	2738	5	51.328	1.291
615-56	0.542	0.007	14.446	0.191	0.193	0.001	1.849	0.023	2776	12	2787	28	2768	6	36.587	1.137
615-57	0.545	0.005	14.371	0.118	0.191	0.000	1.834	0.015	2773	8	2806	18	2750	3	217.167	8.921
615-58	0.531	0.004	13.865	0.119	0.189	0.001	1.883	0.014	2739	8	2746	17	2735	5	61.601	1.537
615-59	0.534	0.005	13.945	0.139	0.189	0.001	1.874	0.017	2743	9	2756	21	2733	6	47.486	1.234
615-60	0.527	0.006	13.914	0.146	0.191	0.001	1.898	0.020	2741	10	2728	23	2751	5	92.858	5.802
615-61	0.526	0.003	13.795	0.099	0.190	0.000	1.900	0.012	2735	7	2726	14	2742	4	109.285	1.797
615-62	0.530	0.005	13.923	0.140	0.190	0.001	1.885	0.018	2744	10	2743	21	2744	6	44.452	1.233
615-63	0.528	0.005	13.803	0.126	0.189	0.001	1.896	0.017	2733	9	2731	20	2734	5	53.019	1.369
615-64	0.536	0.006	13.965	0.171	0.189	0.001	1.848	0.023	2754	12	2788	28	2730	6	235.761	12.962
615-65	0.533	0.009	13.948	0.236	0.190	0.001	1.867	0.030	2751	16	2765	36	2741	7	99.489	6.383
615-66	0.535	0.006	14.048	0.179	0.190	0.001	1.852	0.021	2758	11	2783	25	2740	7	156.126	5.666
615-67	0.525	0.007	13.411	0.186	0.185	0.001	1.889	0.025	2714	13	2739	29	2695	6	177.767	10.932
615-68*	0.510	0.009	13.181	0.233	0.187	0.001	1.950	0.032	2694	16	2668	36	2713	5	666.235	55.100
615-69*	0.512	0.009	13.076	0.241	0.185	0.001	1.941	0.033	2689	16	2678	37	2697	6	163.453	4.239

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
615-70	0.534	0.007	13.684	0.198	0.185	0.001	1.850	0.027	2737	14	2786	33	2702	7	150.151	8.051
615-71*	0.512	0.009	13.139	0.252	0.186	0.001	1.948	0.036	2690	18	2671	41	2705	5	453.176	50.204
615-72*	0.563	0.009	14.420	0.233	0.186	0.001	1.760	0.027	2786	15	2900	35	2704	6	192.078	14.341
615-73	0.512	0.006	13.077	0.150	0.185	0.001	1.932	0.021	2693	11	2688	24	2697	6	206.972	10.701
615-74	0.535	0.007	13.682	0.170	0.185	0.001	1.851	0.023	2734	12	2785	28	2698	6	160.132	5.949
615-75	0.520	0.006	13.336	0.156	0.185	0.001	1.897	0.021	2712	11	2730	25	2700	5	363.708	22.868
615-76	0.549	0.012	14.177	0.323	0.188	0.001	1.829	0.043	2761	23	2811	53	2725	8	81.952	3.339
615-77	0.535	0.008	13.828	0.223	0.188	0.001	1.858	0.027	2747	14	2776	33	2726	6	133.539	5.900
615-78*	0.564	0.020	14.540	0.510	0.188	0.001	1.826	0.056	2763	30	2816	70	2725	11	44.061	2.445
615-79	0.535	0.006	13.761	0.159	0.188	0.001	1.858	0.023	2744	12	2776	27	2720	6	157.711	7.465
615-80	0.538	0.010	13.936	0.280	0.188	0.001	1.860	0.036	2746	19	2773	44	2726	9	80.538	2.529
615-81	0.545	0.011	14.064	0.279	0.188	0.001	1.837	0.035	2756	19	2802	44	2723	7	85.418	4.352
615-82	0.518	0.006	13.397	0.170	0.188	0.001	1.923	0.023	2713	12	2699	27	2724	6	184.271	8.181
615-83	0.534	0.010	13.901	0.290	0.187	0.001	1.886	0.036	2729	19	2743	43	2719	9	70.337	2.280
	616 (least altered)															
616-1	0.540	0.006	14.263	0.162	0.191	0.001	1.855	0.020	2763	11	2779	24	2752	7	48.777	1.482
616-2	0.522	0.006	13.638	0.141	0.190	0.001	1.919	0.021	2725	11	2704	24	2740	7	43.217	2.053
616-3	0.541	0.004	14.250	0.126	0.191	0.001	1.848	0.014	2766	8	2789	17	2749	7	67.433	2.001
616-4	0.532	0.004	13.961	0.117	0.190	0.001	1.879	0.016	2745	9	2751	19	2741	5	59.681	0.635
616-5	0.530	0.005	13.833	0.130	0.189	0.001	1.886	0.017	2737	9	2742	20	2733	7	42.067	1.595
616-6	0.530	0.005	13.815	0.127	0.189	0.001	1.883	0.017	2740	9	2746	20	2735	5	49.595	1.111
616-7	0.536	0.005	14.013	0.138	0.189	0.001	1.867	0.019	2749	10	2765	22	2737	5	55.238	2.207
616-8	0.523	0.005	13.792	0.142	0.191	0.001	1.914	0.018	2732	10	2710	21	2748	6	42.940	1.702
616-9	0.510	0.004	13.467	0.120	0.191	0.001	1.963	0.014	2711	8	2654	16	2753	6	158.577	5.001
616-10	0.531	0.005	13.755	0.141	0.188	0.001	1.885	0.018	2733	10	2744	22	2725	6	46.490	1.412
616-11	0.530	0.005	13.754	0.129	0.188	0.001	1.893	0.018	2730	10	2734	22	2727	5	49.244	0.657
616-12	0.556	0.006	14.400	0.155	0.188	0.001	1.806	0.018	2774	10	2841	23	2726	5	48.807	2.474
616-13	0.530	0.003	13.859	0.096	0.190	0.001	1.890	0.011	2738	6	2738	13	2738	5	97.338	1.755

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
616-14	0.525	0.006	13.648	0.179	0.188	0.001	1.906	0.023	2724	12	2719	27	2728	7	30.644	0.710
616-15	0.534	0.004	13.908	0.112	0.189	0.001	1.872	0.014	2741	8	2758	17	2729	4	76.845	2.190
616-16	0.527	0.005	13.726	0.138	0.189	0.001	1.901	0.018	2728	9	2725	21	2730	5	50.937	1.481
616-17	0.531	0.004	13.884	0.113	0.190	0.001	1.887	0.014	2740	8	2741	16	2739	5	66.279	0.633
616-18	0.526	0.004	13.700	0.109	0.189	0.000	1.906	0.014	2727	7	2719	16	2733	4	133.921	1.979
616-19	0.531	0.007	13.961	0.183	0.191	0.001	1.892	0.024	2744	13	2735	29	2750	6	36.009	1.381
616-20	0.512	0.004	13.531	0.122	0.192	0.000	1.956	0.016	2716	8	2662	18	2755	4	148.657	1.409
616-21*	0.516	0.005	13.791	0.142	0.193	0.001	1.937	0.019	2733	10	2683	22	2771	6	54.734	0.751
616-22*	0.542	0.006	14.437	0.162	0.193	0.001	1.845	0.020	2779	11	2792	24	2770	7	63.210	0.595
616-23	0.553	0.020	14.417	0.568	0.190	0.001	1.854	0.063	2757	33	2780	77	2740	13	43.818	2.802
616-24	0.549	0.005	14.272	0.161	0.189	0.001	1.818	0.018	2774	10	2826	23	2736	6	177.763	6.969
616-25	0.574	0.031	15.190	0.925	0.190	0.002	1.894	0.067	2738	35	2733	79	2742	14	31.079	1.528
616-26	0.590	0.007	15.346	0.173	0.190	0.000	1.691	0.019	2845	11	2995	26	2740	4	374.390	8.739
616-27	0.556	0.006	14.479	0.155	0.191	0.001	1.796	0.018	2791	10	2853	24	2746	5	285.411	9.032
616-28	0.536	0.005	13.993	0.147	0.191	0.001	1.858	0.019	2762	10	2776	23	2751	5	232.756	15.732
616-29	0.527	0.008	13.430	0.202	0.186	0.001	1.890	0.026	2721	14	2738	31	2708	6	196.787	12.373
616-30	0.546	0.016	14.452	0.470	0.189	0.001	1.875	0.049	2744	25	2756	58	2736	9	54.718	3.559
616-31	0.520	0.008	13.543	0.229	0.187	0.001	1.940	0.028	2702	14	2680	31	2719	6	165.985	12.806
616-32	0.591	0.030	15.316	0.781	0.187	0.001	1.814	0.062	2762	33	2830	78	2712	13	38.136	2.292
616-33*	0.571	0.013	14.744	0.336	0.186	0.001	1.750	0.037	2793	21	2913	49	2707	8	84.833	7.583
616-34	0.562	0.008	14.511	0.211	0.186	0.001	1.778	0.024	2779	14	2876	31	2709	8	109.760	4.012
616-35	0.529	0.012	13.727	0.315	0.186	0.001	1.897	0.042	2717	22	2729	50	2708	9	73.665	5.017
616-36	0.542	0.007	14.047	0.170	0.187	0.001	1.845	0.021	2747	12	2791	26	2714	7	159.387	9.161
616-37	0.545	0.013	14.022	0.340	0.186	0.001	1.855	0.040	2736	21	2779	49	2704	10	79.151	5.378
616-38*	0.609	0.019	15.644	0.469	0.186	0.001	1.685	0.050	2829	29	3003	72	2708	12	49.559	1.820
616-39	0.574	0.035	14.821	0.893	0.188	0.002	1.878	0.085	2737	44	2751	101	2727	16	27.572	1.709
616-40	0.542	0.019	14.064	0.505	0.188	0.001	1.870	0.056	2742	29	2762	67	2727	12	49.221	3.090
616-41	0.556	0.011	14.424	0.275	0.188	0.001	1.796	0.034	2778	19	2853	44	2724	9	64.091	2.812

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
616-42	0.552	0.016	14.244	0.405	0.187	0.001	1.844	0.048	2750	25	2793	59	2718	10	51.975	2.920
616-43	0.624	0.063	16.253	1.686	0.188	0.001	1.890	0.074	2729	38	2737	87	2724	12	34.264	2.572
616-44*	0.614	0.011	15.897	0.264	0.187	0.001	1.617	0.026	2875	16	3104	40	2719	7	89.007	4.575
616-45	0.540	0.012	13.999	0.334	0.187	0.001	1.842	0.040	2749	21	2795	50	2716	9	59.300	3.526
616-46	0.544	0.009	14.052	0.224	0.187	0.001	1.838	0.030	2750	16	2800	37	2714	9	86.970	4.720
616-47	0.556	0.006	14.419	0.155	0.188	0.001	1.791	0.018	2779	10	2860	24	2721	5	167.799	9.325
616-48	0.560	0.011	14.567	0.302	0.188	0.001	1.789	0.037	2781	20	2862	47	2723	9	63.482	1.627
616-49	0.553	0.009	14.330	0.260	0.188	0.001	1.814	0.029	2767	16	2831	36	2721	9	84.391	4.769
616-50	0.543	0.011	14.016	0.275	0.188	0.001	1.860	0.032	2744	17	2773	39	2722	7	108.884	4.599
616-51	0.549	0.019	14.029	0.485	0.187	0.001	1.875	0.057	2730	29	2755	68	2711	12	41.886	2.345
	618 (strongly altered)															
618-1	0.542	0.026	14.133	0.687	0.189	0.002	1.969	0.082	2698	40	2648	91	2736	13	31.115	1.559
618-2	0.510	0.008	13.291	0.226	0.189	0.001	1.964	0.033	2699	16	2653	36	2733	7	197.576	14.679
618-3	0.543	0.005	14.155	0.126	0.189	0.000	1.825	0.016	2770	8	2817	19	2737	3	429.601	18.717
618-4	0.571	0.050	15.010	1.323	0.191	0.002	2.038	0.133	2671	62	2574	139	2746	16	16.443	1.095
	619 (moderately altered)															
619-1	0.523	0.006	13.737	0.180	0.190	0.001	1.923	0.023	2724	12	2699	26	2742	6	121.456	6.640
619-2	0.541	0.025	14.299	0.634	0.194	0.002	1.965	0.080	2722	39	2652	89	2775	15	28.467	1.296
619-3	0.538	0.018	14.117	0.455	0.190	0.001	1.907	0.056	2733	29	2718	65	2744	13	39.504	1.339
619-4	0.509	0.006	13.256	0.152	0.189	0.001	1.973	0.022	2695	11	2643	24	2735	7	115.521	7.718
619-5	0.521	0.010	13.601	0.256	0.190	0.001	1.924	0.031	2721	16	2698	35	2738	8	72.618	3.691
619-6	0.512	0.008	13.391	0.190	0.190	0.001	1.971	0.028	2701	14	2645	31	2743	7	96.787	4.025
	620 (strongly altered)															
620-1	0.524	0.011	13.820	0.324	0.191	0.001	1.924	0.037	2726	19	2698	42	2747	10	57.398	3.072
620-2	0.519	0.008	13.619	0.208	0.190	0.001	1.943	0.031	2714	16	2677	34	2743	8	77.876	3.189
620-3	0.495	0.005	12.861	0.128	0.189	0.001	2.030	0.019	2666	9	2582	20	2730	5	236.053	10.921
620-4	0.503	0.004	13.459	0.110	0.194	0.000	1.992	0.016	2709	8	2622	17	2775	4	1418.794	79.875
620-5	0.491	0.006	12.697	0.179	0.189	0.001	2.032	0.025	2666	13	2580	26	2732	9	167.746	2.075

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
620-6	0.509	0.004	13.361	0.121	0.190	0.001	1.963	0.018	2702	9	2654	19	2739	5	232.517	8.939
620-7	0.569	0.026	14.903	0.692	0.190	0.001	1.841	0.067	2763	35	2797	83	2739	13	35.740	3.805
620-8	0.509	0.011	13.350	0.281	0.190	0.001	1.970	0.039	2701	19	2647	42	2742	10	66.128	4.326
620-9	0.521	0.008	13.462	0.209	0.187	0.001	1.919	0.030	2712	15	2704	34	2718	5	168.021	4.204
620-10	0.515	0.006	13.438	0.156	0.189	0.001	1.937	0.022	2712	12	2683	25	2733	6	175.676	9.824
620-11	0.505	0.005	13.144	0.152	0.189	0.001	1.984	0.021	2689	11	2632	23	2733	6	125.090	5.551
620-13	0.515	0.006	13.466	0.153	0.189	0.001	1.938	0.023	2710	12	2682	26	2731	6	38.609	1.829
620-14	0.530	0.005	13.717	0.152	0.188	0.001	1.889	0.019	2731	10	2739	23	2725	6	209.077	13.344
620-15	0.547	0.011	14.469	0.306	0.191	0.001	1.841	0.038	2771	20	2797	47	2752	7	131.763	5.904
620-16	0.516	0.007	13.639	0.195	0.192	0.001	1.952	0.027	2717	14	2667	30	2755	7	75.889	3.378
620-17	0.521	0.007	13.770	0.187	0.191	0.001	1.926	0.025	2728	13	2696	29	2752	6	89.874	3.665
620-18	0.518	0.008	13.690	0.218	0.192	0.001	1.934	0.030	2728	15	2687	34	2759	9	134.316	8.080
620-19	0.505	0.009	13.275	0.235	0.191	0.001	1.987	0.036	2697	18	2628	39	2749	10	67.233	2.472
620-20	0.538	0.006	14.198	0.152	0.191	0.001	1.860	0.020	2758	11	2773	24	2747	5	138.213	1.962
620-21	0.494	0.008	12.953	0.209	0.191	0.001	2.032	0.032	2674	15	2580	33	2746	7	109.790	2.270
620-22	0.520	0.007	13.714	0.196	0.191	0.001	1.927	0.026	2729	13	2694	30	2754	8	99.750	3.854
620-23	0.502	0.008	13.346	0.217	0.193	0.001	2.000	0.032	2699	16	2614	34	2764	10	75.103	3.633
620-24	0.510	0.008	13.073	0.235	0.187	0.001	1.964	0.032	2688	17	2653	35	2714	12	114.763	1.599
620-25	0.551	0.008	14.070	0.217	0.187	0.001	1.821	0.028	2762	15	2822	35	2719	8	113.603	3.429
620-26	0.530	0.023	13.938	0.656	0.189	0.002	1.972	0.067	2697	33	2644	74	2736	16	31.717	3.059
620-27	0.543	0.027	14.056	0.690	0.191	0.002	1.949	0.076	2714	38	2670	85	2747	14	30.970	2.245
620-28	0.506	0.006	13.023	0.154	0.186	0.001	1.978	0.023	2679	12	2638	25	2710	7	130.087	5.187
620-29	0.511	0.005	13.153	0.139	0.187	0.001	1.958	0.019	2691	10	2660	21	2714	5	180.716	10.438
620-30	0.497	0.005	12.717	0.134	0.187	0.001	2.018	0.020	2661	10	2595	21	2711	6	188.337	14.309
620-31	0.519	0.005	13.295	0.131	0.187	0.001	1.924	0.020	2705	10	2698	22	2711	5	250.452	9.206
620-32	0.559	0.007	14.411	0.192	0.188	0.001	1.795	0.023	2778	12	2854	29	2723	5	193.651	7.909
620-33	0.519	0.010	13.231	0.250	0.186	0.001	1.941	0.036	2694	18	2678	41	2706	8	65.582	3.839
620-34	0.501	0.010	13.194	0.301	0.188	0.001	1.980	0.040	2685	20	2635	44	2723	9	52.634	2.017

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
620-35	0.533	0.010	13.799	0.253	0.187	0.001	1.877	0.034	2734	18	2754	41	2719	8	69.575	3.326
620-36	0.527	0.011	13.625	0.281	0.188	0.001	1.893	0.037	2726	19	2734	43	2721	8	68.654	3.602
620-37*	0.531	0.011	13.849	0.310	0.188	0.001	1.878	0.039	2733	21	2752	47	2720	9	49.677	1.178
620-38	0.499	0.005	12.846	0.150	0.186	0.001	1.998	0.020	2666	10	2616	22	2704	6	169.813	6.829
620-39	0.545	0.011	14.178	0.332	0.187	0.001	1.824	0.038	2757	21	2818	47	2712	11	48.853	2.119
620-40	0.511	0.007	13.194	0.189	0.187	0.001	1.949	0.025	2696	13	2669	28	2716	8	98.681	2.685
620-41	0.485	0.007	12.742	0.235	0.190	0.001	2.059	0.031	2659	16	2552	32	2742	12	130.537	5.552
620-42	0.529	0.006	13.641	0.147	0.187	0.001	1.898	0.021	2722	11	2728	25	2718	6	142.039	7.344
620-43	0.513	0.007	13.254	0.186	0.188	0.001	1.957	0.025	2696	13	2661	28	2722	7	95.985	2.092
620-44	0.536	0.007	13.775	0.171	0.187	0.001	1.878	0.024	2731	13	2751	28	2715	6	130.567	6.622
620-45	0.549	0.010	14.170	0.262	0.188	0.001	1.830	0.033	2760	17	2810	40	2723	8	64.077	3.654
620-46	0.534	0.013	13.712	0.333	0.187	0.001	1.865	0.041	2738	21	2767	49	2716	10	55.578	4.346
620-47	0.515	0.005	13.233	0.141	0.186	0.001	1.943	0.020	2695	10	2676	23	2709	5	181.800	10.978
620-48	0.551	0.010	14.211	0.274	0.188	0.001	1.835	0.033	2757	18	2804	41	2722	9	73.442	3.139
620-49	0.543	0.008	13.946	0.206	0.186	0.001	1.843	0.026	2746	14	2794	32	2711	7	119.061	7.151
620-50	0.514	0.006	13.278	0.186	0.187	0.001	1.949	0.025	2698	13	2670	28	2719	8	107.640	3.669
620-51	0.532	0.018	14.021	0.463	0.190	0.002	1.936	0.061	2714	31	2684	69	2737	13	29.489	1.034
620-52	0.549	0.036	14.051	0.641	0.189	0.001	1.924	0.035	2719	18	2698	40	2734	7	108.258	3.133
620-53	0.546	0.008	14.382	0.220	0.189	0.001	1.839	0.027	2760	14	2799	33	2732	8	82.447	4.368
620-54	0.516	0.006	13.536	0.168	0.189	0.001	1.933	0.023	2712	12	2688	26	2730	8	100.796	3.406
620-55	0.536	0.014	14.165	0.376	0.190	0.001	1.904	0.039	2732	20	2721	45	2741	9	58.744	2.048
620-56	0.526	0.009	13.882	0.257	0.189	0.001	1.912	0.030	2724	16	2712	35	2733	10	93.064	4.457
620-57	0.617	0.041	16.205	1.033	0.190	0.002	1.812	0.090	2777	48	2833	114	2737	15	23.068	1.435
	621 (strongly altered) Protolith Ages															
621-2	0.527	0.011	13.988	0.307	0.191	0.001	1.908	0.041	2734	21	2716	48	2747	10	52.363	2.429
621-3	0.554	0.032	14.778	0.890	0.192	0.002	2.005	0.075	2692	36	2608	80	2755	13	32.276	1.410
621-4	0.502	0.013	13.280	0.341	0.190	0.001	2.013	0.048	2680	23	2600	51	2742	11	52.370	2.443
621-5	0.519	0.011	13.711	0.311	0.190	0.001	1.950	0.038	2711	19	2669	42	2743	11	50.304	2.332

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
621-8	0.522	0.017	13.809	0.445	0.191	0.001	1.963	0.059	2709	29	2654	66	2750	12	41.138	1.993
621-9	0.516	0.008	13.583	0.209	0.190	0.001	1.953	0.030	2708	15	2665	34	2740	9	72.883	3.266
621-10	0.522	0.007	13.847	0.189	0.191	0.001	1.928	0.026	2725	13	2694	30	2748	6	98.171	4.413
621-11	0.514	0.010	13.583	0.277	0.192	0.001	1.967	0.036	2714	18	2649	40	2762	8	61.942	3.181
621-12	0.521	0.014	13.781	0.371	0.192	0.001	1.935	0.050	2727	25	2686	56	2759	10	43.341	1.942
621-13	0.527	0.011	13.990	0.289	0.193	0.001	1.913	0.039	2743	20	2711	45	2767	8	66.761	3.259
621-14	0.541	0.023	14.429	0.628	0.193	0.001	1.946	0.058	2727	29	2673	65	2768	12	37.197	1.769
621-15	0.524	0.008	13.913	0.236	0.192	0.001	1.894	0.030	2749	16	2733	35	2760	8	76.295	2.137
621-17	0.512	0.008	13.494	0.216	0.191	0.001	1.949	0.028	2718	14	2670	31	2753	8	87.937	5.443
621-18	0.515	0.009	13.510	0.242	0.191	0.001	1.939	0.033	2721	17	2682	38	2751	9	68.457	3.063
621-19	0.527	0.010	13.854	0.241	0.192	0.001	1.890	0.033	2748	17	2738	39	2755	8	77.904	5.200
621-20	0.561	0.010	14.650	0.276	0.189	0.001	1.799	0.033	2783	18	2849	42	2736	7	80.246	4.793
621-23	0.533	0.013	13.960	0.331	0.190	0.001	1.897	0.044	2735	23	2730	51	2739	9	50.736	2.165
621-24	0.544	0.016	14.248	0.435	0.190	0.002	1.882	0.054	2742	28	2747	64	2739	13	33.768	1.389
621-26	0.522	0.014	13.692	0.377	0.189	0.001	1.959	0.048	2701	24	2658	53	2733	9	46.733	1.814
621-28	0.531	0.013	13.955	0.346	0.190	0.001	1.899	0.045	2736	23	2727	52	2744	10	59.097	3.548
621-30	0.523	0.012	13.583	0.332	0.191	0.001	1.934	0.043	2722	22	2687	49	2747	11	48.558	1.564
621-34	0.517	0.008	13.494	0.199	0.191	0.001	1.926	0.029	2729	15	2696	34	2754	8	85.584	4.943
621-35	0.522	0.010	13.540	0.268	0.189	0.001	1.922	0.038	2719	20	2701	44	2733	9	57.798	2.409
621-36	0.533	0.019	13.839	0.505	0.190	0.001	1.966	0.055	2701	27	2651	60	2738	12	42.663	2.669
621-38	0.523	0.008	13.592	0.211	0.191	0.001	1.914	0.030	2733	15	2710	34	2750	8	83.969	4.189
621-41	0.528	0.004	13.574	0.117	0.186	0.001	1.885	0.015	2723	8	2743	18	2709	5	202.361	9.240
621-42	0.537	0.013	13.952	0.349	0.188	0.001	1.872	0.042	2737	22	2759	50	2721	12	42.594	1.764
621-43	0.540	0.008	13.938	0.219	0.187	0.001	1.853	0.029	2743	15	2782	35	2715	8	96.443	6.429
621-44	0.551	0.007	14.107	0.170	0.185	0.001	1.809	0.022	2757	12	2837	28	2700	6	151.763	4.188
621-45	0.528	0.007	13.551	0.176	0.185	0.001	1.897	0.024	2713	13	2729	29	2701	6	150.697	8.464
621-46	0.517	0.008	13.451	0.222	0.189	0.001	1.947	0.031	2704	16	2672	35	2729	8	87.186	4.832
621-47	0.524	0.007	13.724	0.171	0.190	0.001	1.895	0.023	2738	12	2732	28	2742	6	131.550	3.489

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
621-48	0.531	0.007	13.884	0.182	0.190	0.001	1.885	0.024	2745	12	2743	28	2746	6	146.760	7.648
621-49	0.534	0.005	14.029	0.137	0.190	0.000	1.870	0.016	2751	9	2762	20	2743	4	265.019	12.411
621-50	0.548	0.009	14.454	0.250	0.192	0.001	1.828	0.028	2780	16	2813	35	2755	10	75.765	1.334
621-51	0.554	0.029	14.579	0.794	0.190	0.002	1.928	0.090	2722	45	2693	103	2744	16	26.330	1.365
621-53	0.539	0.010	14.248	0.280	0.191	0.001	1.869	0.035	2755	18	2763	42	2749	8	63.508	1.486
621-54	0.532	0.018	13.940	0.488	0.189	0.001	1.928	0.054	2716	28	2693	62	2733	12	38.960	1.923
621-55	0.535	0.009	13.827	0.226	0.189	0.001	1.882	0.029	2737	15	2747	35	2729	6	112.019	10.959
621-58	0.527	0.005	13.608	0.131	0.188	0.001	1.905	0.018	2724	9	2720	21	2728	5	236.801	6.010
621-59	0.534	0.013	13.950	0.359	0.190	0.001	1.869	0.041	2750	21	2762	49	2741	10	64.680	4.708
621-62	0.536	0.019	13.885	0.495	0.189	0.001	1.921	0.061	2719	31	2701	70	2732	12	39.098	1.804
621-63	0.541	0.016	13.994	0.418	0.189	0.001	1.896	0.047	2730	24	2731	55	2729	11	44.926	2.258
621-64	0.519	0.008	13.695	0.216	0.191	0.001	1.902	0.028	2737	15	2724	33	2747	8	103.244	8.293
621-66	0.547	0.019	14.654	0.542	0.192	0.001	1.865	0.057	2763	30	2768	69	2759	12	34.056	1.598
621-70	0.527	0.014	14.044	0.392	0.192	0.001	1.894	0.049	2746	26	2733	58	2755	13	36.133	1.927
621-75	0.499	0.006	13.070	0.161	0.191	0.001	2.004	0.023	2687	12	2609	25	2746	6	127.465	5.556
621-80	0.535	0.008	14.138	0.244	0.191	0.001	1.885	0.028	2748	15	2744	34	2751	9	80.046	4.134
621-83	0.528	0.012	14.090	0.328	0.193	0.001	1.913	0.043	2744	22	2710	50	2769	8	57.712	1.578
621-84	0.543	0.008	14.282	0.222	0.190	0.001	1.828	0.028	2769	15	2813	34	2738	9	152.009	8.882
621-87	0.584	0.014	15.794	0.441	0.193	0.001	1.721	0.042	2845	24	2953	57	2770	10	65.567	3.278
621-89	0.555	0.008	14.452	0.205	0.189	0.001	1.785	0.024	2788	13	2868	31	2731	5	217.049	17.466
621-90	0.591	0.021	15.550	0.571	0.191	0.001	1.731	0.056	2826	31	2939	76	2747	9	103.983	16.197
621-91	0.583	0.026	15.509	0.698	0.192	0.001	1.808	0.074	2793	39	2837	93	2761	12	33.614	1.941
621-92	0.564	0.008	14.741	0.211	0.190	0.001	1.759	0.025	2807	14	2902	33	2740	7	125.639	5.045
	621-Group 1 (strongly altered)															
621-1	0.036	0.000	0.262	0.003	0.053	0.001	27.858	0.237	235	3	227	2	308	23	824.146	44.099
621-6	0.084	0.001	0.699	0.012	0.060	0.001	12.012	0.111	535	7	515	5	620	33	171.419	7.782
621-7	0.082	0.001	0.687	0.012	0.060	0.001	12.170	0.110	526	7	509	4	600	33	186.704	5.022
621-16	0.313	0.005	4.935	0.106	0.115	0.001	3.197	0.051	1814	15	1754	24	1883	16	130.594	10.205

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
621-21*	0.024	0.000	0.175	0.003	0.052	0.000	41.220	0.721	162	3	155	3	273	10	9196.975	613.931
621-22	0.177	0.021	2.120	0.277	0.084	0.003	6.799	0.320	1006	36	885	39	1282	59	21.101	1.333
621-25	0.089	0.001	0.741	0.010	0.060	0.001	11.235	0.093	561	6	550	4	607	22	304.632	11.769
621-27	0.104	0.001	0.878	0.009	0.061	0.000	9.618	0.076	639	5	638	5	646	14	714.753	24.961
621-29	0.135	0.001	1.345	0.024	0.072	0.001	7.407	0.085	865	9	816	9	992	22	251.973	9.446
621-31	0.154	0.002	1.579	0.021	0.075	0.001	6.524	0.075	967	9	919	10	1075	16	361.931	17.141
621-32	0.121	0.002	1.583	0.029	0.095	0.001	8.293	0.123	963	10	734	10	1529	15	502.510	10.341
621-33	0.037	0.000	0.267	0.005	0.052	0.001	26.731	0.316	242	4	237	3	290	35	571.981	20.050
621-37	0.054	0.001	0.450	0.012	0.061	0.001	18.455	0.269	380	9	340	5	630	53	133.615	3.508
621-39	0.179	0.002	1.810	0.024	0.073	0.001	5.600	0.057	1048	9	1059	10	1023	17	234.293	15.340
621-40	0.093	0.001	0.760	0.011	0.059	0.001	10.749	0.097	573	7	573	5	573	26	268.343	10.334
621-52+	0.036	0.000	0.253	0.004	0.051	0.001	27.818	0.241	229	3	228	2	242	32	393.735	18.100
621-56+	0.177	0.001	1.817	0.019	0.075	0.000	5.664	0.048	1052	7	1048	8	1059	10	416.240	6.039
621-57+	0.055	0.000	0.407	0.005	0.053	0.000	18.058	0.159	348	4	347	3	348	18	1155.003	79.298
621-60	0.177	0.002	2.026	0.029	0.083	0.001	5.663	0.073	1126	10	1048	12	1278	13	276.811	1.998
621-61	0.112	0.002	1.149	0.021	0.075	0.000	8.960	0.135	778	9	682	10	1063	11	1050.545	45.279
621-65	0.191	0.001	2.090	0.022	0.079	0.000	5.178	0.037	1151	6	1138	8	1174	11	289.730	17.146
621-67	0.036	0.000	0.264	0.004	0.052	0.001	27.138	0.289	237	3	233	2	271	25	735.613	15.656
621-68	0.035	0.000	0.304	0.009	0.062	0.002	28.182	0.363	271	7	225	3	688	58	108.886	3.506
621-69	0.170	0.002	1.766	0.026	0.075	0.001	5.825	0.071	1039	10	1021	11	1076	16	362.852	8.781
621-71+	0.036	0.000	0.261	0.004	0.053	0.001	28.011	0.217	236	4	226	2	335	33	588.292	18.402
621-72	0.035	0.000	0.263	0.005	0.054	0.001	28.436	0.288	238	4	223	2	386	39	413.051	18.775
621-74+	0.035	0.000	0.299	0.012	0.060	0.002	28.310	0.372	261	9	224	3	615	76	130.500	2.871
621-76+	0.094	0.001	0.832	0.019	0.064	0.001	10.575	0.128	614	11	582	7	731	43	117.870	3.243
621-77*	0.016	0.000	0.111	0.002	0.051	0.001	62.422	0.505	108	2	102	1	223	36	1080.271	97.675
621-78+*	0.033	0.000	0.251	0.004	0.055	0.001	30.167	0.291	229	3	210	2	424	26	984.864	15.458
621-79	0.034	0.000	0.249	0.004	0.054	0.001	29.822	0.357	225	4	213	3	352	31	832.994	28.146
621-81*	0.063	0.001	0.526	0.015	0.060	0.001	15.956	0.196	426	10	392	5	616	53	173.752	7.328

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
621-82	0.101	0.002	0.888	0.020	0.063	0.001	9.912	0.162	638	10	620	10	704	29	221.890	18.795
621-85	0.128	0.001	1.162	0.011	0.066	0.000	7.760	0.071	786	5	781	7	798	7	1716.361	90.004
621-86	0.038	0.000	0.268	0.003	0.051	0.000	26.064	0.263	242	2	243	2	236	11	4280.476	195.593
621-88*	0.018	0.000	0.126	0.002	0.052	0.000	56.254	0.677	122	2	114	1	283	18	5538.740	290.603
	622-Group 1 (strongly altered)															
622-1	0.521	0.018	13.773	0.474	0.194	0.002	1.946	0.064	2730	32	2673	72	2772	15	42.365	1.506
622-2	0.529	0.008	14.040	0.215	0.192	0.001	1.896	0.028	2748	15	2730	33	2761	8	99.459	2.432
622-5	0.545	0.011	14.292	0.302	0.193	0.001	1.845	0.035	2775	19	2792	43	2763	10	69.285	1.442
622-9	0.522	0.005	13.799	0.134	0.192	0.001	1.913	0.017	2738	9	2711	19	2757	5	191.916	9.617
622-10	0.514	0.007	13.578	0.198	0.192	0.001	1.952	0.028	2718	14	2666	31	2757	8	81.713	4.308
622-11	0.604	0.010	15.799	0.291	0.189	0.001	1.665	0.028	2853	16	3032	40	2729	6	106.994	6.150
622-16	0.527	0.006	13.662	0.160	0.188	0.001	1.891	0.022	2727	12	2737	26	2720	7	107.852	5.091
622-17	0.520	0.008	13.369	0.223	0.188	0.001	1.924	0.031	2713	16	2698	36	2724	8	81.519	4.282
622-21	0.519	0.007	14.026	0.188	0.193	0.001	1.923	0.025	2738	13	2699	28	2766	7	113.025	5.011
622-26	0.513	0.004	13.829	0.112	0.193	0.000	1.946	0.015	2725	7	2673	16	2763	4	268.371	14.985
622-27	0.509	0.009	13.198	0.238	0.189	0.001	1.963	0.033	2701	16	2654	36	2736	7	122.986	14.247
622-28	0.514	0.005	13.539	0.136	0.191	0.001	1.940	0.019	2721	10	2680	22	2751	6	148.762	7.968
622-29	0.518	0.005	13.632	0.127	0.192	0.001	1.928	0.017	2729	9	2694	20	2756	5	165.849	7.194
622-30	0.520	0.010	13.676	0.262	0.192	0.001	1.928	0.035	2729	18	2694	40	2756	9	65.527	4.014
622-31	0.521	0.007	13.781	0.201	0.192	0.001	1.925	0.027	2731	14	2697	31	2756	8	82.576	3.084
622-34	0.536	0.008	14.133	0.195	0.192	0.000	1.865	0.026	2762	13	2768	32	2757	2	1026.300	20.067
622-38	0.535	0.005	13.957	0.141	0.189	0.001	1.864	0.018	2749	9	2768	21	2735	5	198.568	9.780
622-40	0.527	0.012	13.682	0.299	0.189	0.001	1.890	0.043	2733	22	2738	50	2730	11	49.699	2.627
622-41	0.512	0.008	13.476	0.220	0.190	0.001	1.948	0.032	2712	16	2671	35	2743	9	69.033	2.022
622-43	0.501	0.008	12.943	0.237	0.186	0.001	1.999	0.034	2668	17	2615	36	2709	8	85.842	3.326
622-44	0.521	0.009	13.332	0.216	0.185	0.001	1.915	0.030	2702	16	2708	35	2698	8	67.565	1.884
622-45	0.528	0.015	13.700	0.402	0.188	0.001	1.898	0.054	2727	28	2728	63	2725	11	44.559	2.000
622-46	0.528	0.013	13.497	0.328	0.185	0.001	1.905	0.046	2710	23	2720	53	2702	10	48.980	1.216

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
622-47	0.517	0.014	13.456	0.382	0.187	0.001	1.929	0.050	2704	25	2693	57	2712	12	44.957	1.925
622-48	0.519	0.010	13.252	0.248	0.185	0.001	1.907	0.034	2706	17	2718	40	2697	7	67.816	2.664
622-49	0.524	0.011	13.491	0.293	0.186	0.001	1.899	0.034	2716	18	2727	40	2708	10	81.401	6.332
622-50	0.531	0.011	13.925	0.303	0.190	0.001	1.878	0.039	2747	20	2752	47	2744	8	89.443	6.934
622-51	0.554	0.013	14.427	0.347	0.188	0.001	1.808	0.042	2774	23	2838	54	2727	8	60.288	1.964
622-52	0.527	0.006	13.864	0.166	0.190	0.001	1.876	0.021	2746	11	2754	25	2740	6	154.784	4.549
622-53	0.559	0.011	14.713	0.280	0.191	0.001	1.790	0.035	2796	19	2861	45	2749	8	82.835	3.854
622-55	0.538	0.008	14.070	0.227	0.189	0.001	1.855	0.030	2751	16	2780	36	2731	7	100.458	4.132
622-56	0.523	0.007	13.636	0.214	0.188	0.001	1.897	0.029	2727	15	2729	34	2726	8	115.104	6.943
622-57	0.566	0.021	14.878	0.548	0.190	0.001	1.820	0.050	2775	27	2822	63	2740	10	73.139	6.182
622-58	0.547	0.012	14.503	0.340	0.191	0.001	1.826	0.041	2775	22	2815	52	2746	9	74.896	2.961
622-60	0.537	0.008	14.010	0.215	0.189	0.001	1.858	0.028	2749	15	2775	34	2730	6	137.655	5.254
622-61	0.555	0.007	14.260	0.183	0.187	0.001	1.804	0.021	2769	12	2844	27	2715	6	130.158	4.275
622-62	0.535	0.011	13.683	0.257	0.187	0.001	1.876	0.035	2732	18	2754	42	2716	6	123.167	6.696
622-63	0.559	0.007	14.322	0.187	0.187	0.001	1.791	0.023	2774	12	2859	30	2712	4	211.291	5.700
622-64	0.535	0.012	13.891	0.327	0.189	0.001	1.882	0.045	2739	24	2747	54	2733	10	66.361	3.082
622-66	0.609	0.031	15.963	0.934	0.188	0.001	1.724	0.070	2818	39	2948	96	2726	13	39.883	3.094
622-67	0.554	0.008	14.146	0.212	0.186	0.001	1.806	0.026	2764	14	2841	33	2708	6	127.746	4.979
622-68	0.529	0.007	13.991	0.192	0.193	0.001	1.876	0.025	2759	13	2754	29	2763	6	173.805	5.210
622-69	0.539	0.013	14.306	0.334	0.194	0.001	1.862	0.042	2772	22	2771	51	2772	8	68.247	3.057
622-70	0.500	0.006	12.738	0.164	0.185	0.001	1.976	0.025	2674	12	2640	27	2701	6	394.461	22.232
622-71	0.593	0.009	15.365	0.221	0.189	0.001	1.676	0.025	2847	15	3016	36	2729	5	346.710	11.151
622-72	0.526	0.007	13.847	0.195	0.192	0.001	1.886	0.027	2750	14	2742	31	2756	7	106.970	3.234
622-73	0.540	0.008	14.213	0.232	0.191	0.001	1.836	0.027	2774	15	2803	34	2754	7	122.406	6.645
622-76	0.550	0.009	14.504	0.257	0.192	0.001	1.806	0.031	2792	17	2841	39	2756	7	109.616	4.052
622-77	0.538	0.011	14.145	0.295	0.192	0.001	1.866	0.039	2760	20	2766	47	2755	9	77.816	4.265
622-78	0.582	0.008	15.241	0.209	0.191	0.000	1.712	0.024	2838	14	2965	34	2749	3	898.011	51.050
622-80	0.585	0.022	14.986	0.562	0.187	0.001	1.764	0.056	2792	31	2895	74	2719	12	60.346	8.155

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
622-82	0.583	0.006	15.137	0.150	0.189	0.000	1.705	0.017	2832	9	2975	23	2731	3	694.908	52.550
622-83	0.550	0.007	14.414	0.201	0.191	0.001	1.813	0.024	2782	13	2832	30	2746	6	136.808	3.778
622-84	0.516	0.007	13.327	0.179	0.188	0.001	1.934	0.025	2709	13	2687	29	2725	6	146.929	4.187
622-85	0.553	0.006	14.405	0.172	0.190	0.001	1.799	0.021	2785	12	2850	26	2738	6	160.959	3.755
622-86	0.508	0.004	13.270	0.119	0.189	0.000	1.946	0.017	2708	9	2673	19	2733	4	345.899	12.881
622-87	0.550	0.013	14.179	0.358	0.187	0.001	1.827	0.042	2755	23	2814	52	2712	12	66.763	2.603
622-88	0.542	0.014	14.417	0.400	0.192	0.001	1.849	0.049	2771	26	2787	60	2759	11	55.708	2.540
622-89	0.535	0.012	14.209	0.305	0.192	0.001	1.869	0.042	2762	22	2763	50	2760	8	77.644	3.451
	622-Group 2 (strongly altered)															
622-3	0.515	0.004	12.600	0.108	0.178	0.000	1.947	0.016	2651	8	2672	17	2636	4	325.700	9.785
622-4	0.518	0.008	12.861	0.211	0.181	0.001	1.953	0.031	2664	15	2666	35	2662	5	365.813	32.550
622-6	0.493	0.004	12.103	0.106	0.177	0.000	2.028	0.017	2609	8	2584	18	2628	3	805.437	25.098
622-7	0.479	0.005	11.695	0.110	0.178	0.001	2.087	0.021	2584	10	2523	21	2631	6	315.036	21.527
622-8	0.494	0.004	12.419	0.095	0.182	0.000	2.025	0.015	2634	7	2587	16	2670	4	883.577	65.573
622-12	0.489	0.004	12.026	0.090	0.178	0.000	2.042	0.015	2607	7	2570	16	2635	4	491.418	10.674
622-13	0.620	0.010	15.669	0.271	0.183	0.001	1.612	0.027	2853	17	3111	42	2675	7	98.907	6.659
622-14	0.483	0.004	11.561	0.098	0.174	0.000	2.057	0.016	2576	8	2554	17	2594	5	472.884	24.941
622-15**	0.165	0.002	1.679	0.023	0.074	0.000	6.036	0.073	1006	8	988	11	1044	8	999.080	24.975
622-18	0.449	0.008	10.892	0.183	0.175	0.000	2.243	0.047	2504	20	2376	42	2608	4	636.080	42.267
622-19	0.471	0.004	11.830	0.118	0.179	0.001	2.113	0.020	2580	9	2498	19	2645	5	378.932	14.886
622-20	0.493	0.004	12.454	0.096	0.180	0.001	2.021	0.015	2627	7	2591	16	2654	5	267.091	5.269
622-22	0.518	0.006	12.957	0.174	0.179	0.000	1.925	0.024	2666	12	2697	27	2642	4	643.241	21.406
622-23	0.510	0.004	12.805	0.093	0.180	0.001	1.956	0.014	2657	7	2662	16	2653	5	313.654	13.360
622-24	0.533	0.005	13.264	0.125	0.178	0.000	1.877	0.019	2687	10	2754	22	2638	4	281.975	5.658
622-25	0.488	0.003	12.251	0.075	0.180	0.000	2.042	0.012	2615	6	2569	12	2650	4	636.354	28.745
622-32	0.506	0.004	12.344	0.094	0.178	0.000	1.978	0.015	2635	7	2638	16	2633	4	292.232	12.576
622-33	0.486	0.004	11.842	0.098	0.177	0.000	2.052	0.016	2597	8	2559	17	2627	3	745.843	36.338
622-35	0.513	0.008	12.499	0.205	0.176	0.000	1.948	0.031	2638	15	2670	35	2613	4	610.933	28.324

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
622-36	0.485	0.004	11.861	0.109	0.177	0.000	2.051	0.017	2596	8	2560	18	2624	4	409.994	29.210
622-37	0.464	0.005	11.450	0.123	0.178	0.000	2.137	0.024	2564	11	2475	23	2635	4	626.773	58.747
622-39	0.477	0.003	11.547	0.073	0.175	0.000	2.086	0.012	2571	6	2525	12	2608	3	835.301	42.622
622-42	0.511	0.006	12.457	0.154	0.176	0.000	1.955	0.023	2637	11	2663	26	2617	4	420.194	25.427
622-54	0.547	0.007	13.746	0.181	0.182	0.001	1.818	0.022	2733	12	2825	28	2666	6	181.350	2.148
622-59	0.531	0.007	12.917	0.171	0.176	0.001	1.873	0.023	2674	12	2758	28	2611	5	287.343	17.698
622-65	0.527	0.012	13.248	0.302	0.183	0.001	1.926	0.044	2688	22	2696	50	2682	9	59.566	2.231
622-74	0.502	0.007	12.452	0.180	0.181	0.000	1.974	0.027	2652	13	2641	30	2659	3	1358.669	37.539
622-75	0.535	0.006	13.207	0.148	0.179	0.000	1.849	0.021	2706	11	2787	25	2646	4	609.860	22.251
622-79	0.544	0.009	13.030	0.231	0.174	0.000	1.837	0.029	2685	15	2801	36	2598	4	541.643	33.989
622-81	0.488	0.009	11.894	0.215	0.177	0.000	2.055	0.037	2596	17	2556	38	2627	3	1239.140	82.368
	624 (strongly altered)															
624-1	0.524	0.014	13.731	0.393	0.190	0.001	1.911	0.050	2731	26	2714	58	2745	12	43.632	2.398
	625 (strongly altered)															
625-1	0.528	0.008	13.778	0.197	0.190	0.001	1.892	0.028	2738	14	2735	32	2740	8	109.347	7.294
625-2	0.507	0.006	13.134	0.172	0.189	0.001	1.985	0.024	2687	12	2630	27	2729	7	107.314	4.372
625-3	0.490	0.012	12.756	0.313	0.191	0.001	2.066	0.049	2660	24	2545	50	2749	12	47.554	1.776
	260-Group 1 (moderately altered)															
260-1	0.533	0.0095	13.88	0.3143	0.189	0.0010	1.86	0.0329	2749	17	2770	40	2734	9	62.307	4.068
260-2	0.569	0.0071	14.88	0.2414	0.190	0.0006	1.75	0.0228	2816	13	2917	31	2744	5	137.527	15.713
260-3	0.526	0.0075	13.79	0.2735	0.190	0.0008	1.89	0.0287	2739	15	2738	34	2739	7	70.134	4.085
260-4	0.528	0.0106	13.87	0.3483	0.190	0.0009	1.88	0.0376	2743	19	2747	45	2739	8	47.146	2.563
260-5	0.541	0.0089	14.01	0.2880	0.190	0.0005	1.85	0.0284	2763	15	2787	35	2745	4	122.627	8.348
260-6	0.534	0.0051	14.05	0.1814	0.190	0.0006	1.86	0.0174	2752	9	2769	21	2740	5	194.829	20.936
260-7	0.532	0.0103	13.91	0.2868	0.190	0.0010	1.88	0.0352	2746	18	2749	42	2743	9	47.376	2.970
260-8	0.536	0.0176	13.99	0.5259	0.190	0.0012	1.86	0.0567	2755	30	2774	69	2741	11	29.693	1.968
260-9	0.532	0.0056	14.02	0.1982	0.190	0.0006	1.87	0.0201	2748	11	2756	24	2743	5	131.075	5.982
260-10	0.530	0.0060	13.87	0.1962	0.190	0.0007	1.88	0.0212	2742	11	2745	25	2741	6	97.612	3.455

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
260-11	0.559	0.0079	14.79	0.2074	0.189	0.0008	1.79	0.0250	2788	14	2862	32	2735	7	57.819	2.142
260-12	0.546	0.0092	14.11	0.2721	0.190	0.0007	1.83	0.0304	2771	16	2808	38	2744	6	45.161	2.475
260-13	0.555	0.0112	14.50	0.3616	0.191	0.0009	1.80	0.0331	2791	18	2849	42	2751	8	37.109	2.934
260-14	0.531	0.0109	13.99	0.3532	0.191	0.0012	1.87	0.0359	2753	19	2759	43	2749	10	30.242	1.197
260-15	0.548	0.0099	14.45	0.3436	0.192	0.0007	1.82	0.0322	2784	17	2819	40	2758	6	45.886	5.013
260-16	0.546	0.0084	14.37	0.2503	0.191	0.0009	1.83	0.0289	2775	16	2814	36	2747	8	38.044	0.984
260-17	0.544	0.0075	14.48	0.2781	0.191	0.0009	1.82	0.0269	2781	15	2821	34	2753	8	45.998	2.291
260-18	0.540	0.0085	14.23	0.3106	0.192	0.0009	1.85	0.0297	2766	16	2780	36	2755	8	38.041	2.094
260-19	0.549	0.0090	14.64	0.3257	0.192	0.0009	1.82	0.0303	2782	16	2819	38	2755	8	48.894	3.685
260-20	0.538	0.0072	14.00	0.2211	0.189	0.0007	1.85	0.0258	2752	14	2780	31	2731	6	68.950	3.589
260-21	0.546	0.0099	14.08	0.3437	0.188	0.0009	1.84	0.0329	2757	18	2798	41	2728	8	40.183	3.296
260-22	0.543	0.0101	14.14	0.2770	0.188	0.0008	1.84	0.0333	2755	18	2796	41	2725	7	47.303	1.660
260-23	0.529	0.0112	13.60	0.3323	0.189	0.0011	1.90	0.0383	2731	20	2729	45	2732	9	32.246	1.344
260-25	0.535	0.0094	13.83	0.2737	0.188	0.0008	1.88	0.0331	2738	17	2754	40	2727	7	52.251	2.598
260-26	0.533	0.0100	13.68	0.3013	0.188	0.0008	1.88	0.0357	2736	18	2748	42	2727	7	45.739	3.159
260-28	0.525	0.0074	13.91	0.2113	0.191	0.0007	1.91	0.0275	2735	14	2720	32	2746	6	53.905	4.626
260-29	0.532	0.0079	14.09	0.2635	0.191	0.0005	1.88	0.0276	2749	14	2752	33	2746	4	105.563	6.663
260-30	0.560	0.0100	14.87	0.2682	0.190	0.0007	1.78	0.0298	2800	16	2878	39	2745	6	75.947	6.711
260-31	0.546	0.0084	14.30	0.2282	0.190	0.0006	1.82	0.0244	2776	13	2826	31	2741	6	73.359	2.702
260-32	0.540	0.0078	14.31	0.2297	0.190	0.0008	1.85	0.0255	2763	14	2787	31	2745	7	50.301	3.015
260-33	0.534	0.0065	14.16	0.2131	0.191	0.0006	1.87	0.0236	2753	12	2761	28	2747	5	84.587	7.224
260-34	0.537	0.0077	14.11	0.2562	0.189	0.0007	1.86	0.0279	2747	15	2771	34	2729	6	78.571	2.978
260-35	0.533	0.0115	14.23	0.3224	0.190	0.0010	1.87	0.0410	2749	21	2756	49	2744	9	33.208	1.633
260-36	0.542	0.0080	14.12	0.2237	0.189	0.0006	1.86	0.0269	2753	14	2777	33	2736	5	71.527	3.615
260-37	0.537	0.0116	13.73	0.3629	0.188	0.0010	1.88	0.0400	2736	21	2751	48	2725	9	35.390	1.457
260-38	0.537	0.0090	13.94	0.3099	0.189	0.0008	1.86	0.0308	2747	16	2770	37	2729	7	51.556	2.141
260-40	0.540	0.0126	13.86	0.3931	0.190	0.0011	1.87	0.0431	2752	23	2767	52	2742	10	28.091	1.765
260-41	0.539	0.0102	13.73	0.3435	0.188	0.0009	1.87	0.0364	2740	19	2763	44	2723	8	39.175	1.684

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
260-42	0.544	0.0080	14.08	0.2534	0.189	0.0007	1.84	0.0269	2759	14	2795	33	2732	6	55.014	2.021
260-43	0.546	0.0094	14.16	0.2733	0.189	0.0006	1.84	0.0316	2763	17	2803	39	2734	6	61.120	2.235
260-44	0.552	0.0107	14.42	0.3482	0.189	0.0008	1.82	0.0366	2772	20	2827	46	2733	7	75.044	7.362
260-45	0.554	0.0085	14.29	0.2717	0.189	0.0008	1.80	0.0300	2781	16	2845	38	2734	7	53.567	2.454
260-74	0.516	0.0082	13.11	0.2283	0.188	0.0006	1.93	0.0323	2709	16	2686	37	2727	6	166.647	20.611
260-82	0.569	0.0059	14.59	0.2198	0.188	0.0009	1.76	0.0185	2798	11	2900	25	2725	8	157.512	4.689
	260-Group 2 (moderately altered)															
260-24	0.574	0.0073	14.51	0.2343	0.186	0.0010	1.74	0.0215	2796	13	2922	29	2706	9	74.518	4.262
260-27	0.535	0.0112	13.68	0.3391	0.187	0.0012	1.88	0.0375	2734	20	2755	45	2718	11	33.544	1.851
260-39*	0.473	0.0119	12.13	0.4063	0.187	0.0009	2.11	0.0553	2624	25	2505	54	2717	8	43.114	6.936
260-46	0.547	0.0108	13.90	0.3161	0.185	0.0009	1.83	0.0366	2743	19	2810	46	2694	8	61.968	4.172
260-47	0.534	0.0095	13.56	0.3043	0.185	0.0007	1.88	0.0334	2722	17	2755	40	2697	7	79.175	3.198
260-48	0.537	0.0088	13.66	0.2171	0.184	0.0006	1.85	0.0295	2727	15	2783	36	2686	6	116.468	8.809
260-49	0.537	0.0110	13.98	0.3343	0.185	0.0009	1.85	0.0423	2732	22	2781	52	2696	8	91.309	13.280
260-50	0.536	0.0098	13.65	0.3338	0.184	0.0010	1.87	0.0343	2724	18	2767	41	2692	9	73.221	5.273
260-51	0.535	0.0057	13.80	0.1896	0.185	0.0006	1.86	0.0197	2727	10	2768	24	2697	5	196.656	8.111
260-52	0.531	0.0143	13.50	0.3634	0.185	0.0011	1.88	0.0460	2716	24	2747	55	2693	9	49.137	2.455
260-53	0.547	0.0077	14.09	0.2712	0.184	0.0006	1.82	0.0254	2749	14	2826	32	2693	6	108.561	7.938
260-54	0.524	0.0093	13.13	0.2931	0.182	0.0008	1.89	0.0309	2699	16	2735	36	2673	7	96.634	7.694
260-55	0.532	0.0103	13.39	0.3050	0.184	0.0006	1.88	0.0327	2717	17	2753	39	2691	5	164.231	22.736
260-56	0.541	0.0071	13.70	0.2302	0.185	0.0006	1.84	0.0250	2741	13	2803	31	2695	6	125.119	6.681
260-57	0.534	0.0148	13.36	0.3628	0.184	0.0010	1.88	0.0500	2714	26	2744	59	2691	9	52.534	2.042
260-58	0.540	0.0098	13.70	0.2810	0.186	0.0009	1.84	0.0337	2741	18	2793	41	2702	8	83.619	5.572
260-59	0.547	0.0083	13.82	0.2470	0.185	0.0008	1.81	0.0282	2754	15	2834	36	2695	7	106.249	4.476
260-60	0.535	0.0056	13.57	0.2004	0.185	0.0007	1.86	0.0189	2728	10	2773	23	2695	6	136.639	5.148
260-61	0.526	0.0106	13.09	0.3475	0.184	0.0013	1.90	0.0399	2704	21	2727	47	2686	11	53.066	3.405
260-62	0.551	0.0075	13.89	0.2529	0.185	0.0006	1.80	0.0253	2758	14	2847	32	2694	5	174.370	18.034
260-63	0.534	0.0088	13.41	0.2675	0.185	0.0007	1.85	0.0345	2735	18	2780	42	2702	6	83.363	2.589

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
260-64	0.540	0.0053	13.66	0.1798	0.185	0.0004	1.85	0.0182	2731	10	2783	22	2693	3	226.380	6.855
260-65	0.527	0.0064	13.31	0.2139	0.184	0.0006	1.90	0.0224	2708	12	2731	26	2691	5	124.670	3.162
260-66	0.564	0.0083	14.10	0.2004	0.183	0.0007	1.76	0.0251	2771	14	2894	33	2683	6	149.098	13.256
260-67	0.559	0.0164	14.21	0.3972	0.185	0.0011	1.79	0.0533	2767	29	2868	69	2695	10	52.715	3.099
260-68	0.584	0.0193	14.73	0.4169	0.186	0.0010	1.72	0.0571	2806	32	2950	78	2705	9	42.921	1.364
260-69*	0.729	0.0233	18.23	0.6426	0.183	0.0011	1.37	0.0404	3016	29	3543	81	2682	10	50.161	3.554
260-70	0.523	0.0098	13.09	0.3081	0.183	0.0009	1.91	0.0362	2692	18	2709	42	2678	9	65.323	4.136
260-71	0.520	0.0128	12.89	0.3314	0.183	0.0010	1.93	0.0475	2687	24	2693	54	2682	9	51.248	2.660
260-72	0.524	0.0107	13.00	0.3240	0.184	0.0010	1.90	0.0371	2704	19	2721	43	2691	9	62.046	1.854
260-73	0.547	0.0071	13.85	0.2309	0.185	0.0007	1.82	0.0243	2750	13	2821	31	2698	7	89.201	3.517
260-75	0.542	0.0068	13.85	0.2178	0.186	0.0005	1.84	0.0221	2747	12	2803	27	2706	4	171.838	9.187
260-76	0.534	0.0088	13.61	0.2554	0.186	0.0008	1.86	0.0312	2732	16	2772	38	2702	7	148.708	15.707
260-77	0.542	0.0097	13.62	0.2892	0.185	0.0009	1.83	0.0319	2745	17	2804	40	2701	8	74.798	3.149
260-78	0.522	0.0052	13.33	0.1862	0.186	0.0006	1.91	0.0187	2708	10	2715	22	2702	5	253.073	23.124
260-79	0.560	0.0076	14.25	0.2212	0.184	0.0006	1.77	0.0250	2771	14	2881	33	2692	5	153.521	7.159
260-80	0.542	0.0075	13.86	0.2165	0.186	0.0008	1.84	0.0257	2744	14	2799	32	2704	8	98.561	1.874
260-81	0.537	0.0058	13.68	0.1942	0.186	0.0005	1.86	0.0197	2737	10	2774	24	2710	4	348.186	21.348
260-83	0.561	0.0124	14.22	0.3740	0.186	0.0008	1.78	0.0396	2778	22	2874	52	2709	7	53.792	1.635
260-84	0.524	0.0102	13.49	0.2727	0.187	0.0009	1.92	0.0363	2705	18	2698	42	2711	8	76.116	2.746
260-85	0.541	0.0056	13.87	0.2033	0.187	0.0006	1.85	0.0192	2746	10	2786	23	2717	5	169.660	8.566
260-86	0.546	0.0052	13.91	0.1946	0.187	0.0006	1.83	0.0180	2752	10	2805	22	2714	5	238.992	14.707
260-87	0.548	0.0106	13.81	0.3261	0.186	0.0009	1.83	0.0310	2751	17	2816	39	2704	8	89.482	8.842
260-88	0.543	0.0059	13.90	0.2261	0.187	0.0005	1.85	0.0202	2746	11	2791	25	2714	4	318.903	7.096
260-89	0.553	0.0119	13.81	0.3436	0.185	0.0010	1.81	0.0404	2756	22	2835	51	2698	9	59.372	3.114
260-90	0.547	0.0126	13.68	0.3695	0.185	0.0009	1.86	0.0418	2730	22	2778	51	2694	8	64.423	2.314
260-91	0.558	0.0067	14.03	0.2279	0.184	0.0006	1.80	0.0212	2755	12	2843	27	2690	5	170.255	12.862
260-92	0.540	0.0066	13.50	0.2228	0.184	0.0006	1.86	0.0242	2725	13	2773	29	2689	6	165.090	9.874
260-93	0.537	0.0061	13.57	0.2153	0.184	0.0005	1.86	0.0219	2722	11	2771	27	2685	5	179.606	9.573

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
260-94	0.542	0.0079	13.47	0.2573	0.184	0.0007	1.85	0.0254	2728	13	2780	31	2689	6	104.927	7.379
	261-Group 1 (least altered)															
261-1	0.521	0.0113	12.86	0.3061	0.180	0.0005	1.94	0.0420	2661	21	2678	47	2648	5	1324.693	100.064
261-4	0.574	0.0107	14.28	0.3384	0.182	0.0008	1.74	0.0323	2775	18	2923	44	2670	8	74.943	5.337
261-5	0.549	0.0051	13.65	0.1926	0.182	0.0006	1.83	0.0164	2732	9	2814	20	2672	5	218.881	9.752
261-7	0.544	0.0067	13.51	0.2204	0.182	0.0007	1.85	0.0224	2718	12	2784	27	2670	6	208.999	31.897
261-9	0.546	0.0069	13.36	0.2186	0.181	0.0008	1.84	0.0223	2719	12	2803	28	2658	8	107.141	7.768
261-10	0.548	0.0056	13.56	0.2067	0.181	0.0006	1.83	0.0190	2727	10	2814	24	2663	5	156.406	8.888
261-26*	0.712	0.0246	17.93	0.6903	0.182	0.0009	1.42	0.0498	2974	34	3439	94	2673	8	108.704	2.881
	261-Group 2 (least altered)															
261-2	0.559	0.0083	13.98	0.2322	0.182	0.0007	1.80	0.0268	2748	15	2849	34	2674	6	104.115	5.944
261-3	0.553	0.0060	13.59	0.1827	0.182	0.0007	1.82	0.0195	2737	11	2823	24	2675	6	132.746	5.381
261-6	0.568	0.0092	14.08	0.3063	0.183	0.0008	1.77	0.0293	2764	16	2885	38	2677	8	111.957	17.194
261-8	0.587	0.0126	14.68	0.2874	0.183	0.0009	1.70	0.0367	2802	21	2975	51	2679	8	81.191	3.002
261-11	0.556	0.0093	14.33	0.3051	0.187	0.0007	1.80	0.0284	2770	15	2846	36	2716	7	60.762	3.006
261-12	0.545	0.0096	14.00	0.2321	0.186	0.0009	1.84	0.0307	2745	16	2796	38	2707	8	42.349	2.911
261-13	0.536	0.0087	13.75	0.2562	0.187	0.0008	1.87	0.0321	2737	17	2763	39	2718	7	42.284	2.228
261-14	0.556	0.0123	14.21	0.3698	0.187	0.0008	1.81	0.0403	2762	21	2832	51	2712	7	40.501	2.060
261-15	0.534	0.0111	13.59	0.3028	0.186	0.0009	1.87	0.0384	2729	20	2758	46	2707	8	43.638	1.510
261-16	0.536	0.0062	13.81	0.1935	0.187	0.0006	1.86	0.0212	2737	11	2770	26	2713	6	109.620	8.491
261-17	0.548	0.0101	13.92	0.3549	0.187	0.0009	1.84	0.0334	2751	18	2802	41	2715	8	43.516	2.534
261-18	0.546	0.0057	14.18	0.1970	0.186	0.0006	1.83	0.0198	2753	11	2811	25	2710	5	98.841	4.837
261-19	0.540	0.0078	13.87	0.2388	0.187	0.0009	1.85	0.0277	2743	15	2783	34	2714	8	41.182	2.750
261-20	0.535	0.0084	13.80	0.2607	0.187	0.0008	1.87	0.0307	2735	16	2756	37	2719	7	56.712	3.164
261-21	0.541	0.0085	13.73	0.2546	0.186	0.0011	1.85	0.0290	2739	16	2788	36	2703	10	43.438	2.381
261-22	0.555	0.0141	14.17	0.4197	0.186	0.0009	1.81	0.0471	2764	25	2840	60	2709	8	33.771	1.575
261-23	0.552	0.0153	14.01	0.4093	0.187	0.0011	1.82	0.0489	2757	26	2819	61	2711	9	29.629	2.485
261-24	0.528	0.0135	13.55	0.3782	0.186	0.0012	1.91	0.0454	2711	23	2715	53	2708	11	29.099	1.301

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
261-25	0.538	0.0063	13.95	0.1906	0.187	0.0007	1.85	0.0219	2745	12	2787	27	2715	6	75.117	3.140
261-27	0.546	0.0050	14.05	0.2078	0.187	0.0007	1.83	0.0166	2755	9	2811	21	2714	6	101.267	4.816
261-28	0.551	0.0100	14.09	0.3091	0.186	0.0008	1.83	0.0319	2752	17	2813	40	2707	7	65.802	5.443
261-29	0.533	0.0102	13.58	0.2863	0.186	0.0010	1.88	0.0363	2725	19	2749	43	2708	9	58.872	7.539
261-30	0.538	0.0105	13.74	0.2852	0.187	0.0009	1.87	0.0355	2734	18	2762	43	2713	8	41.586	2.168
261-31	0.561	0.0073	14.68	0.2504	0.187	0.0006	1.78	0.0240	2785	13	2879	31	2717	6	110.689	2.872
261-32	0.538	0.0095	13.77	0.2698	0.187	0.0009	1.86	0.0343	2737	18	2768	41	2715	8	36.636	1.967
261-33	0.553	0.0071	14.21	0.2513	0.186	0.0008	1.81	0.0238	2762	13	2833	30	2711	7	65.005	2.384
261-34	0.541	0.0095	13.74	0.3084	0.186	0.0008	1.85	0.0304	2738	16	2780	37	2707	7	49.931	4.361
261-35	0.543	0.0096	13.81	0.3017	0.186	0.0009	1.85	0.0318	2742	17	2786	39	2710	8	45.872	3.162
261-36	0.554	0.0106	14.21	0.3259	0.187	0.0008	1.81	0.0331	2764	18	2830	42	2717	7	47.843	3.459
261-37	0.542	0.0105	13.77	0.3038	0.186	0.0009	1.86	0.0357	2737	19	2772	43	2710	8	45.936	3.521
261-38	0.543	0.0100	13.92	0.2992	0.187	0.0009	1.83	0.0322	2754	17	2813	40	2712	8	45.851	3.802
	262 (strongly altered)															
262-1	0.535	0.0156	12.96	0.4503	0.178	0.0011	1.89	0.0510	2678	26	2733	60	2637	10	41.635	2.519
262-2	0.540	0.0104	13.24	0.3041	0.182	0.0008	1.86	0.0328	2713	17	2776	40	2667	8	69.568	6.612
262-3	0.572	0.0065	13.90	0.2046	0.179	0.0005	1.75	0.0207	2754	12	2913	28	2639	5	178.941	13.134
262-4	0.547	0.0078	13.23	0.2452	0.180	0.0007	1.84	0.0260	2713	14	2800	32	2648	7	97.264	6.219
262-5	0.535	0.0096	13.22	0.2836	0.180	0.0009	1.88	0.0323	2696	17	2754	39	2652	9	61.868	1.501
262-6	0.541	0.0074	13.32	0.2204	0.180	0.0006	1.86	0.0253	2707	13	2778	31	2655	6	101.786	8.187
262-7	0.546	0.0097	13.45	0.2802	0.180	0.0007	1.83	0.0299	2716	16	2806	37	2649	7	60.039	2.471
262-8	0.552	0.0168	13.50	0.4683	0.180	0.0010	1.87	0.0460	2701	24	2763	55	2654	9	67.476	11.534
262-9	0.552	0.0199	13.51	0.5190	0.180	0.0011	1.85	0.0585	2705	30	2780	71	2650	10	39.156	2.116
262-10	0.526	0.0107	12.92	0.3215	0.181	0.0009	1.91	0.0400	2688	20	2717	47	2666	9	57.108	4.077
262-11	0.544	0.0084	13.28	0.2163	0.178	0.0007	1.85	0.0282	2699	15	2784	34	2636	6	91.327	7.220
262-12	0.531	0.0049	13.04	0.1611	0.180	0.0005	1.89	0.0191	2692	10	2743	23	2654	5	166.155	4.623
262-13	0.525	0.0071	12.97	0.2025	0.179	0.0008	1.91	0.0257	2670	13	2710	30	2639	8	78.911	4.668
262-14	0.524	0.0053	12.94	0.2129	0.180	0.0006	1.92	0.0198	2675	10	2708	23	2649	5	146.998	6.571

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
262-15	0.452	0.1863	10.93	4.6856	0.179	0.0008	1.86	0.0350	2702	18	2779	43	2645	7	82.830	6.832
262-16	0.533	0.0057	13.01	0.1760	0.178	0.0005	1.88	0.0204	2684	11	2748	24	2636	5	124.295	6.853
262-17	0.537	0.0076	13.23	0.2236	0.180	0.0007	1.86	0.0255	2699	13	2768	31	2648	6	84.292	6.087
262-18	0.548	0.0061	13.47	0.1536	0.179	0.0006	1.84	0.0201	2713	11	2803	25	2647	6	112.056	2.634
262-19	0.538	0.0104	13.19	0.3143	0.179	0.0010	1.87	0.0333	2694	18	2762	40	2644	9	55.409	2.659
262-20	0.529	0.0070	12.98	0.2281	0.180	0.0006	1.90	0.0233	2687	12	2728	27	2656	6	132.910	11.351
262-21	0.543	0.0059	13.30	0.2051	0.177	0.0006	1.84	0.0203	2699	11	2798	25	2626	6	106.741	5.389
262-22	0.542	0.0061	13.34	0.1829	0.179	0.0005	1.84	0.0193	2706	10	2795	24	2640	5	132.585	7.430
262-23	0.539	0.0041	13.21	0.1771	0.178	0.0005	1.85	0.0130	2696	7	2787	16	2629	4	259.298	20.601
262-24	0.547	0.0104	13.65	0.2789	0.180	0.0010	1.82	0.0344	2727	19	2824	43	2655	9	61.869	3.290
262-25	0.541	0.0137	13.20	0.3585	0.177	0.0010	1.84	0.0462	2702	24	2801	57	2628	10	43.320	2.063
262-26	0.558	0.0085	13.47	0.2140	0.177	0.0006	1.80	0.0264	2723	14	2854	34	2628	6	99.122	5.785
262-27	0.543	0.0087	13.18	0.2692	0.178	0.0009	1.84	0.0310	2704	17	2796	38	2636	8	82.007	7.373
262-28	0.544	0.0077	13.29	0.2199	0.179	0.0009	1.84	0.0262	2708	14	2800	32	2641	8	81.833	4.159
262-29	0.536	0.0065	13.19	0.2030	0.178	0.0007	1.86	0.0227	2695	12	2775	28	2636	7	125.523	5.137
262-30	0.525	0.0057	12.95	0.1800	0.179	0.0007	1.89	0.0210	2682	11	2734	25	2643	7	96.467	3.589
262-31	0.532	0.0068	13.01	0.2178	0.178	0.0007	1.88	0.0235	2681	12	2749	28	2630	6	118.964	8.172
262-32	0.528	0.0069	12.82	0.2249	0.178	0.0009	1.89	0.0243	2677	13	2735	29	2633	8	65.835	2.522
262-33	0.550	0.0095	13.30	0.2940	0.177	0.0008	1.83	0.0313	2703	17	2815	39	2620	8	72.145	5.367
	263-Group 1 (strongly altered)															
263-1	0.532	0.0048	13.16	0.1612	0.179	0.0007	1.88	0.0168	2690	9	2753	20	2643	6	138.174	6.742
263-2	0.530	0.0047	13.05	0.1799	0.178	0.0006	1.89	0.0167	2681	9	2740	20	2637	6	142.410	7.228
263-3	0.535	0.0036	13.27	0.1469	0.179	0.0003	1.87	0.0122	2696	6	2764	15	2645	3	352.459	14.464
263-4	0.520	0.0040	12.84	0.1271	0.179	0.0005	1.92	0.0146	2669	8	2701	17	2645	4	299.606	13.197
263-5	0.530	0.0052	13.04	0.1762	0.179	0.0008	1.89	0.0180	2686	10	2742	21	2645	7	103.556	5.599
263-6	0.514	0.0055	12.51	0.1845	0.177	0.0008	1.94	0.0216	2650	11	2679	24	2628	7	114.619	6.126
263-7	0.542	0.0095	13.09	0.3042	0.178	0.0008	1.84	0.0302	2703	16	2796	37	2635	8	74.854	5.382
	263-Group 2 (strongly altered)															

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
263-8	0.550	0.0058	13.76	0.1683	0.181	0.0007	1.82	0.0197	2732	11	2824	25	2665	7	113.666	5.467
263-9	0.549	0.0084	13.68	0.2688	0.183	0.0010	1.83	0.0273	2731	15	2805	34	2676	9	58.966	2.863
263-10	0.538	0.0051	13.57	0.1706	0.182	0.0007	1.86	0.0180	2711	10	2769	22	2669	6	110.050	6.663
263-11	0.551	0.0047	13.83	0.1635	0.183	0.0004	1.82	0.0155	2737	8	2822	20	2675	4	224.064	6.248
263-12	0.551	0.0059	13.77	0.1984	0.182	0.0006	1.82	0.0188	2735	10	2822	24	2672	5	135.578	9.079
263-13	0.532	0.0058	13.29	0.1787	0.181	0.0006	1.88	0.0183	2702	10	2754	22	2664	6	115.299	3.235
263-14	0.537	0.0129	13.68	0.3577	0.184	0.0014	1.87	0.0446	2715	24	2757	53	2685	12	44.284	2.598
263-15	0.541	0.0096	13.62	0.3085	0.182	0.0009	1.85	0.0326	2722	17	2788	40	2674	8	54.167	2.812
263-16	0.537	0.0055	13.34	0.1638	0.182	0.0005	1.86	0.0178	2714	9	2772	21	2672	5	145.374	6.864
263-17	0.545	0.0117	13.35	0.3372	0.181	0.0009	1.85	0.0401	2715	21	2785	49	2663	9	47.167	2.373
263-18	0.545	0.0106	13.37	0.3208	0.182	0.0008	1.84	0.0368	2723	19	2797	45	2668	7	64.122	4.827
263-19	0.539	0.0129	13.30	0.3831	0.184	0.0010	1.87	0.0425	2717	22	2756	51	2688	9	46.031	2.378
263-20	0.562	0.0095	13.92	0.2759	0.182	0.0009	1.79	0.0294	2752	16	2861	38	2672	8	68.905	3.866
263-21	0.555	0.0111	13.69	0.3176	0.182	0.0010	1.81	0.0328	2743	18	2838	42	2673	9	57.923	1.625
263-22	0.545	0.0077	13.44	0.2431	0.182	0.0008	1.84	0.0245	2723	13	2799	30	2667	7	91.147	4.218
263-23	0.547	0.0057	13.56	0.1888	0.182	0.0005	1.84	0.0192	2729	10	2804	24	2675	5	134.784	3.750
263-24	0.545	0.0052	13.43	0.2101	0.182	0.0007	1.84	0.0189	2724	10	2801	23	2667	6	106.775	1.507
263-25	0.538	0.0113	13.32	0.3212	0.182	0.0011	1.86	0.0361	2715	19	2771	44	2673	10	48.107	2.550
263-26	0.540	0.0066	13.61	0.2110	0.183	0.0005	1.85	0.0227	2723	12	2780	28	2681	5	163.128	11.882
263-27	0.549	0.0096	13.76	0.2826	0.184	0.0006	1.83	0.0321	2740	17	2815	40	2684	6	90.847	4.797
263-28	0.539	0.0091	13.42	0.2637	0.183	0.0008	1.87	0.0313	2715	16	2767	38	2677	7	76.255	5.209
263-29	0.541	0.0069	13.52	0.2520	0.183	0.0008	1.85	0.0230	2722	12	2780	28	2678	7	95.579	7.383
263-30	0.544	0.0102	13.54	0.3195	0.183	0.0010	1.85	0.0354	2724	19	2786	43	2679	9	56.788	2.975
263-31	0.552	0.0070	13.82	0.2246	0.183	0.0006	1.82	0.0228	2741	12	2821	29	2682	5	155.159	8.997
263-32	0.549	0.0078	13.80	0.2313	0.186	0.0009	1.82	0.0266	2753	15	2823	33	2703	8	103.177	6.577
263-33	0.551	0.0079	13.85	0.2331	0.184	0.0007	1.81	0.0242	2747	13	2830	31	2686	7	95.578	5.115
263-34	0.543	0.0073	13.62	0.2463	0.182	0.0008	1.84	0.0251	2727	14	2799	31	2675	7	105.722	3.444
264-Group 1 (strongly altered)																

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
264-1	0.532	0.0106	13.02	0.3169	0.182	0.0009	1.88	0.0390	2701	20	2747	46	2666	8	84.272	6.870
264-2	0.554	0.0093	13.71	0.2754	0.181	0.0009	1.80	0.0307	2740	17	2844	39	2664	8	77.278	4.271
264-3	0.545	0.0086	13.50	0.2493	0.182	0.0007	1.84	0.0287	2722	15	2794	35	2669	7	92.878	5.805
264-4	0.569	0.0088	14.09	0.2503	0.182	0.0007	1.76	0.0270	2768	15	2899	36	2673	6	93.042	4.124
264-5	0.536	0.0059	13.33	0.1850	0.182	0.0006	1.87	0.0205	2709	11	2757	25	2673	6	172.931	7.883
264-6	0.542	0.0083	13.53	0.2405	0.181	0.0008	1.84	0.0292	2718	15	2793	36	2663	7	96.689	5.035
264-7	0.543	0.0068	13.50	0.1852	0.182	0.0008	1.85	0.0235	2722	13	2788	29	2673	7	114.083	6.112
264-8	0.536	0.0089	13.42	0.2838	0.182	0.0008	1.86	0.0309	2714	16	2771	37	2671	8	70.487	1.918
264-9	0.516	0.0109	12.61	0.3309	0.181	0.0009	1.95	0.0432	2667	21	2670	48	2664	8	66.526	7.056
264-21	0.511	0.0149	12.85	0.4487	0.183	0.0010	1.96	0.0554	2671	27	2663	62	2678	9	87.488	10.894
264-22	0.534	0.0062	13.34	0.1976	0.182	0.0006	1.86	0.0209	2716	11	2778	25	2671	5	202.247	8.012
264-23	0.529	0.0121	13.00	0.3377	0.182	0.0009	1.87	0.0415	2705	21	2758	50	2666	8	81.557	6.716
264-24	0.530	0.0135	13.23	0.3719	0.182	0.0012	1.88	0.0491	2704	25	2750	58	2670	11	49.393	3.673
264-25	0.550	0.0073	13.65	0.1883	0.181	0.0008	1.81	0.0242	2737	13	2835	31	2666	7	119.305	8.118
264-26	0.525	0.0100	13.10	0.3120	0.182	0.0010	1.89	0.0369	2697	19	2733	43	2669	9	69.764	3.174
264-27	0.540	0.0068	13.53	0.1923	0.181	0.0006	1.84	0.0231	2722	12	2799	29	2665	5	176.067	12.536
264-28	0.526	0.0077	13.30	0.2346	0.183	0.0008	1.89	0.0269	2702	14	2735	32	2677	7	121.217	2.583
264-29	0.536	0.0081	13.30	0.2547	0.183	0.0009	1.85	0.0274	2727	15	2787	33	2683	8	81.837	4.014
	264-Group 2 (strongly altered)															
264-10	0.563	0.0143	13.92	0.3287	0.185	0.0008	1.78	0.0433	2769	23	2875	56	2694	7	74.196	7.477
264-11	0.562	0.0065	14.14	0.2257	0.185	0.0007	1.78	0.0216	2771	12	2879	28	2694	6	105.581	3.870
264-12	0.543	0.0071	13.75	0.2103	0.186	0.0007	1.84	0.0231	2744	12	2796	28	2706	6	118.395	8.961
264-13	0.580	0.0102	14.65	0.3427	0.186	0.0007	1.72	0.0290	2809	16	2956	40	2705	6	89.690	6.598
264-14	0.542	0.0107	13.62	0.3176	0.185	0.0009	1.85	0.0358	2735	19	2791	44	2695	8	59.950	3.262
264-15	0.537	0.0101	13.52	0.2729	0.186	0.0010	1.86	0.0351	2733	19	2775	43	2703	9	58.119	5.461
264-16	0.536	0.0074	13.49	0.2208	0.185	0.0006	1.86	0.0248	2728	13	2773	30	2694	6	123.860	7.046
264-17	0.544	0.0057	13.74	0.1879	0.185	0.0005	1.83	0.0191	2745	10	2810	24	2698	4	208.836	20.119
264-18	0.540	0.0065	13.60	0.2119	0.185	0.0007	1.85	0.0216	2734	12	2787	26	2695	6	111.918	5.805

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
264-19	0.553	0.0065	13.93	0.2060	0.184	0.0004	1.81	0.0203	2755	11	2840	26	2693	4	258.415	5.693
264-20	0.527	0.0094	13.23	0.2781	0.185	0.0009	1.90	0.0344	2709	18	2728	40	2695	8	44.745	2.842
	265 (strongly altered)															
265-1	0.539	0.0110	13.60	0.3035	0.185	0.0009	1.86	0.0378	2730	20	2773	46	2699	8	65.356	3.564
265-2	0.538	0.0129	13.65	0.3118	0.186	0.0011	1.86	0.0414	2733	22	2770	50	2706	10	53.555	2.608
265-3	0.557	0.0104	14.02	0.3005	0.185	0.0008	1.79	0.0324	2768	18	2861	42	2701	7	71.031	2.387
265-4	0.534	0.0071	13.58	0.2277	0.186	0.0007	1.87	0.0253	2729	13	2765	30	2703	6	105.355	3.879
265-5*	0.581	0.0138	15.18	0.4482	0.190	0.0006	1.73	0.0429	2825	24	2944	59	2741	5	470.089	75.245
265-6	0.545	0.0095	13.75	0.2834	0.186	0.0009	1.84	0.0321	2745	17	2803	40	2703	8	59.053	3.798
265-7	0.565	0.0092	14.33	0.2036	0.187	0.0005	1.77	0.0302	2789	16	2890	40	2717	5	181.850	9.927
265-8	0.538	0.0070	13.77	0.2311	0.186	0.0006	1.86	0.0235	2738	12	2779	29	2708	6	136.742	10.251
	266-Group 1 (moderately altered)															
266-1	0.534	0.0122	12.98	0.3507	0.179	0.0008	1.89	0.0421	2683	21	2743	50	2639	8	55.037	3.024
266-2	0.523	0.0089	13.01	0.2581	0.178	0.0007	1.92	0.0322	2667	16	2705	37	2638	7	81.640	3.940
266-3	0.510	0.0085	12.65	0.2520	0.181	0.0008	1.96	0.0320	2656	16	2652	35	2660	7	95.638	2.011
266-4	0.526	0.0076	13.01	0.2262	0.179	0.0007	1.91	0.0280	2674	14	2714	32	2644	6	94.390	2.380
266-5	0.519	0.0084	12.76	0.2491	0.179	0.0007	1.93	0.0313	2661	16	2688	36	2642	6	139.772	6.542
266-6*	0.574	0.0125	13.94	0.2904	0.177	0.0008	1.75	0.0378	2748	21	2919	51	2625	7	60.294	2.119
266-7	0.526	0.0086	12.93	0.2550	0.178	0.0007	1.91	0.0306	2666	16	2714	35	2629	6	112.392	10.434
266-8	0.511	0.0090	12.57	0.2341	0.178	0.0008	1.96	0.0337	2648	17	2661	38	2637	7	78.656	6.389
266-9	0.538	0.0098	13.44	0.3021	0.180	0.0008	1.85	0.0322	2706	17	2782	39	2650	7	97.439	11.588
266-10*	0.548	0.0248	13.59	0.6508	0.181	0.0014	1.83	0.0834	2727	44	2813	104	2665	13	27.616	2.815
266-11	0.536	0.0067	13.39	0.2102	0.181	0.0008	1.87	0.0224	2706	12	2764	27	2663	7	93.755	3.005
266-12	0.536	0.0066	13.50	0.1925	0.182	0.0004	1.86	0.0219	2710	11	2768	26	2667	4	225.693	12.430
266-13	0.527	0.0067	13.26	0.2067	0.181	0.0006	1.90	0.0242	2693	13	2732	28	2664	6	126.636	7.108
266-14	0.528	0.0078	13.38	0.2561	0.182	0.0008	1.90	0.0292	2697	15	2731	34	2671	7	108.941	9.916
266-15	0.552	0.0075	13.82	0.2265	0.181	0.0008	1.81	0.0251	2736	14	2831	32	2666	7	85.067	3.982
	266-Group 2 (moderately altered)															

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
266-16	0.531	0.0078	13.51	0.2285	0.186	0.0005	1.87	0.0268	2726	14	2756	32	2704	5	163.888	7.450
266-17	0.521	0.0109	13.31	0.3230	0.186	0.0009	1.91	0.0392	2711	20	2718	46	2706	8	54.686	3.756
266-18	0.539	0.0053	13.98	0.1946	0.188	0.0003	1.85	0.0179	2753	9	2791	22	2725	3	736.529	44.295
266-19	0.524	0.0111	13.32	0.2757	0.186	0.0009	1.91	0.0423	2710	21	2717	49	2705	8	52.188	2.025
266-20	0.525	0.0097	13.38	0.2977	0.187	0.0009	1.90	0.0329	2718	17	2722	38	2715	8	68.111	4.072
266-21	0.535	0.0064	13.56	0.1941	0.184	0.0006	1.86	0.0223	2726	12	2773	27	2692	5	112.475	2.012
266-22	0.551	0.0103	14.03	0.2946	0.186	0.0009	1.81	0.0364	2759	20	2838	46	2702	8	62.389	2.021
266-23	0.524	0.0133	13.30	0.3559	0.184	0.0011	1.91	0.0467	2702	24	2715	54	2693	10	52.039	2.222
266-24	0.508	0.0092	12.80	0.2805	0.186	0.0009	1.97	0.0368	2679	18	2649	41	2702	8	73.874	5.338
	628-Group 1 (carbonatite)															
628-5	0.259	0.0030	3.21	0.0481	0.090	0.0003	3.87	0.0446	1455	9	1481	15	1419	7	344.090	27.421
628-7	0.253	0.0028	3.11	0.0414	0.089	0.0005	3.96	0.0421	1433	9	1450	14	1408	11	115.606	6.623
628-8	0.256	0.0036	3.18	0.0585	0.089	0.0006	3.92	0.0557	1443	12	1466	19	1409	14	73.358	3.363
628-10	0.242	0.0026	2.91	0.0431	0.087	0.0005	4.14	0.0468	1381	10	1394	14	1362	11	105.233	4.933
	628-Group 2 (carbonatite)															
628-1	0.485	0.0088	11.70	0.2597	0.177	0.0008	2.06	0.0381	2593	18	2550	39	2628	8	113.638	9.267
628-2	0.536	0.0116	13.18	0.3206	0.179	0.0011	1.86	0.0380	2696	20	2769	46	2641	10	61.115	2.034
628-3	0.476	0.0122	11.99	0.3688	0.181	0.0005	2.10	0.0554	2598	25	2515	55	2663	5	258.569	13.781
628-4	0.497	0.0124	12.07	0.3573	0.179	0.0013	2.02	0.0496	2622	24	2596	53	2643	12	46.038	3.109
628-6	0.537	0.0057	13.30	0.2010	0.178	0.0006	1.86	0.0182	2690	10	2768	22	2632	5	90.101	1.637
628-9	0.517	0.0059	12.89	0.1704	0.180	0.0007	1.94	0.0230	2663	12	2679	26	2651	6	86.818	5.529
628-11	0.540	0.0128	12.96	0.3430	0.177	0.0012	1.87	0.0443	2686	23	2765	53	2628	11	31.356	2.499
628-12	0.484	0.0193	12.16	0.5091	0.179	0.0009	2.08	0.0896	2592	41	2529	90	2643	8	41.600	3.886
628-13	0.572	0.0267	14.10	0.6986	0.180	0.0013	1.81	0.0739	2729	39	2834	94	2651	12	27.445	2.416
628-14	0.559	0.0088	13.85	0.2817	0.180	0.0006	1.80	0.0268	2734	14	2851	34	2648	5	90.927	8.561
628-15	0.536	0.0073	13.36	0.2357	0.180	0.0007	1.87	0.0252	2695	13	2756	30	2649	6	71.222	2.823
	TY128															
TY128-1	0.182	0.0022	1.84	0.0326	0.073	0.0008	5.49	0.0682	1054	11	1080	12	1001	22	119.955	6.820

	206Pb/238U	± 2 (SE)	207Pb/235U	± 2 (SE)	207Pb/206Pb	± 2 (SE)	238U/206Pb	± 2 (SE)	207Pb/235U (Ma)	± 2 (SE)	206Pb/238U (Ma)	± 2 (SE)	207Pb/206Pb (Ma)	± 2 (SE)	U (ppm)	2 SE
TY128-2	0.184	0.0019	1.86	0.0231	0.074	0.0006	5.44	0.0586	1070	9	1088	11	1034	16	249.021	17.560
TY128-3	0.209	0.0026	2.23	0.0293	0.078	0.0004	4.79	0.0588	1193	9	1222	14	1141	11	535.199	19.441
TY128-4	0.192	0.0019	2.01	0.0256	0.076	0.0006	5.21	0.0516	1117	9	1132	10	1088	17	168.164	7.465
TY128-5	0.243	0.0027	2.94	0.0350	0.089	0.0005	4.11	0.0459	1402	10	1405	14	1397	11	284.244	18.593

Appendix C: Sulfur Isotopes

See Section 3.6 for methodology.

Sample ##	Alt. Level	Total %S		Result	Repeat
		Primary	Repeat	δS_{34} VCDT $\pm 0.3\text{‰}$	
602	Weak	0.13	0.15	0.86	1.05
603	Strong	0.95		2.00	
608	Weak	0.92	0.98	1.06	1.12
609	Strong	0.83	0.92	0.87	0.95
610	Strong	1.74		1.43	
613	Moderate	0.60	0.51	1.54	1.51
614	Strong	1.06		1.76	
617	Strong	1.23	1.20	0.90	0.82
618	Strong	2.12	2.29	1.51	1.82
619	Moderate	1.42	1.41	2.04	2.05
620	Strong	1.45	1.55	1.62	1.81
621	Strong	1.47	1.19	1.52	1.59
623	Strong	0.56	0.64	1.88	1.78
624	Strong	2.15	2.02	1.88	1.50
625	Strong	1.47		2.13	
T128	Strong	1.79	1.09	1.36	1.36

Appendix D: Oxygen-Hydrogen Isotopes

See Section 3.5 for methodology.

Sample ID	Alt. Level	$\delta^2\text{H}$ ‰ vs VSMOW	$\delta^{18}\text{O}$ ‰ vs VSMOW
601	Least	-83.38	8.6
602	Weak	-73.71	8.4
603	Strong	-74.48	9.8
604	Least	-76.34	10.5
605	Least	-77.67	9.3
606	Weak	-70.08	9.8
607	Least	-86.74	9.8
608	Weak	-86.68	9.3
609	Strong	-65.11	9.5
610	Strong	-65.08	9.7
611	Strong	-66.17	9.4
612	Weak	-76.76	9.7
613	Moderate	-64.11	9.7
614	Strong	-65.72	9.4
615	Least	-74.46	9.7
616	Least	-66.63	9.5
617	Strong	-68.55	8.9
618	Strong	-68.30	9.8
619	Strong	-71.88	11.5
620	Strong	-69.09	10.6
621	Strong	-75.90	10.7
622	Strong	-59.75	7.8
623	Strong	-60.43	10.9
624	Strong	-75.03	10.9
625	Strong	-69.88	10.2

Appendix E: LA-ICP-MS Zircon Trace Elements

See Section 3.3 for methodology.

	Y (ppm)	± 2SE	Nb (ppm)	± 2SE	Hf (ppm)	± 2SE	Pb 208 (ppm)	± 2SE	Th 232 (ppm)	± 2SE	U238 (ppm)	± 2SE
Sample-spot ##	621-Post-Archean aged											
621-1	2481.06	152.37	3.16	0.72	10386.47	310.09	3.99	0.92	150.11	9.15	579.26	34.78
621-6	608.29	33.60	3.82	0.56	9678.12	431.77	6.87	0.97	105.57	8.53	125.32	8.68
621-7	1297.11	77.49	1.88	0.52	10260.40	417.98	4.34	0.62	73.82	5.91	179.82	15.49
621-21	4146.31	213.13	9.47	1.33	19251.21	1004.44	8.10	1.10	508.82	29.69	9132.39	770.21
621-22	1372.67	57.47	1.98	0.45	8799.39	496.30	2.46	0.64	27.29	3.61	86.46	35.84
621-25	3363.02	140.42	2.71	0.57	11808.80	425.72	7.13	1.45	114.88	7.61	373.88	23.75
621-28	877.94	29.69	3.24	0.58	11064.10	361.46	11.98	1.38	189.41	9.35	760.73	47.77
621-29	653.77	28.45	1.90	0.57	9500.94	354.57	11.92	1.63	107.83	6.85	251.95	14.17
621-31	2496.48	111.23	16.70	1.79	8831.27	336.32	33.58	4.04	280.92	20.36	493.96	25.88
621-32	1891.32	237.41	1.34	0.43	10451.43	315.33	10.85	2.11	74.33	7.60	223.70	19.70
621-33	3380.97	163.58	2.00	0.51	11998.08	534.68	1.03	0.44	62.80	5.40	689.17	42.92
621-37	1084.63	95.14	4.08	0.69	8805.63	416.65	5.98	1.10	152.99	18.82	281.56	27.40
621-39	890.76	40.21	2.63	0.55	11053.96	368.58	7.60	1.08	62.79	3.10	208.29	10.37
621-40	574.43	24.22	3.69	0.71	9962.55	326.54	15.20	1.41	276.39	13.61	244.30	14.74
621-42	371.70	15.32	0.85	0.35	8464.52	268.29	6.05	0.94	20.82	1.92	46.58	2.76
621-52	3091.94	119.98	1.72	0.53	11127.17	505.99	1.45	0.46	71.91	5.40	401.94	23.77
621-56	783.75	30.14	1.34	0.44	12081.77	482.55	4.47	0.93	28.01	2.51	292.50	13.47
621-57	1287.61	40.08	6.35	1.18	11790.83	551.92	16.55	1.67	455.17	15.00	1074.29	114.18
621-60	1844.55	72.82	5.62	1.42	9712.77	313.63	8.46	1.37	82.37	5.38	233.68	14.32
621-61	2109.15	124.19	32.65	1.92	9593.03	417.69	18.35	1.98	169.24	12.44	966.49	48.04
621-65	902.38	54.57	1.99	0.53	11632.36	398.67	3.25	0.87	9.28	1.02	320.67	21.61
621-67	2758.85	105.76	2.62	0.47	10324.25	331.78	1.95	0.50	84.20	4.99	600.52	51.36
621-68	1018.54	37.09	0.90	0.36	7466.94	260.17	1.22	0.37	51.98	3.19	116.32	6.74
621-69	1148.22	55.46	21.76	2.26	8891.31	327.82	4.79	0.85	51.14	5.42	180.62	18.12
621-71	2797.64	107.89	1.96	0.55	10917.96	376.06	1.58	0.63	37.67	2.53	555.07	23.05

	Y (ppm)	± 2SE	Nb (ppm)	± 2SE	Hf (ppm)	± 2SE	Pb 208 (ppm)	± 2SE	Th 232 (ppm)	± 2SE	U238 (ppm)	± 2SE
621-72	3108.08	210.74	1.80	0.62	11060.01	496.68	1.43	0.49	68.88	5.93	686.77	41.56
621-74	1704.19	162.24	2.07	0.57	12206.31	511.34	2.33	0.66	93.74	7.23	667.46	123.15
621-76	349.79	19.82	1.23	0.44	7305.38	239.24	8.82	1.42	115.73	9.30	115.50	8.68
621-77	1339.00	70.66	2.40	0.57	11260.31	433.94	2.61	0.73	264.21	16.30	503.40	31.88
621-78	4245.81	1323.26	3.09	1.30	7808.62	2596.32	0.99	11.33	123.54	68.31	1044.75	568.94
621-79	1785.22	77.05	1.76	0.53	9599.22	449.43	2.57	0.68	126.39	8.83	345.43	23.10
621-81	570.46	50.22	1.55	0.44	9258.42	263.03	3.01	0.91	55.71	6.84	115.09	14.66
621-82	1591.74	83.04	5.04	0.94	9308.84	287.75	29.07	2.32	487.91	17.74	388.36	19.18
621-85	4281.31	194.49	4.64	0.83	16252.79	746.14	7.28	1.12	266.85	19.10	4336.79	473.79
621-86	951.84	58.80	3.17	0.67	10522.93	505.87	4.55	0.81	366.04	25.87	1012.82	65.10
621-88	477.87	30.78	0.51	0.28	8383.62	416.17	9.81	1.36	28.36	2.78	54.66	5.11
	622-Group 2											
622-4	1706.10	127.97	2.28	1.17	10520.29	1104.78	47.40	7.37	173.23	20.82	221.15	26.06
622-7	352.34	35.38	2.23	0.89	10858.50	1013.14	5.01	1.79	13.49	3.22	26.78	3.98
622-8	370.10	26.86	2.23	0.91	10444.86	806.76	6.93	2.33	20.74	2.76	45.57	5.74
622-12	3999.26	284.22	67.86	7.39	11467.15	1117.75	56.32	8.42	249.67	35.09	1238.17	92.38
622-13	354.78	39.57	0.88	0.52	11058.82	1225.66	6.78	2.40	25.92	4.20	45.72	5.75
622-18	309.05	23.01	1.55	0.88	9273.05	744.02	4.76	2.05	18.29	3.12	40.42	8.05
622-19	853.63	105.71	1.61	0.78	8978.41	1002.99	8.26	2.79	41.22	5.62	66.64	10.90
622-20	2642.58	134.29	121.37	11.21	12445.52	831.45	0.11	0.53	0.90	0.56	668.98	65.35
622-23	492.61	42.41	2.33	0.76	8639.29	1046.17	4.54	1.85	19.26	4.08	43.64	6.30
622-25	1214.56	126.70	19.27	2.70	11616.58	1175.29	10.23	2.67	40.11	5.62	535.17	56.33
622-26	296.69	43.34	0.65	0.43	9301.27	937.79	4.23	1.09	18.15	2.53	34.03	5.33
622-32	342.97	173.92	0.29	3.53	10815.67	822.55	3.14	4.44	14.03	14.74	35.48	81.54
622-33	1908.33	30.32	15.67	0.50	9950.03	1020.98	23.38	1.60	114.94	3.56	592.52	7.68
	628-Group 2											
628-6	839.83	80.74	122.62	18.62	2278.25	163.06	70.69	10.40	199.41	34.27	73.03	10.44
628-9	109.20	10.17	0.53	0.44	12095.58	1426.61	2.76	1.66	9.27	2.72	67.15	10.32
628-11	802.51	78.15	2.43	1.10	2738.13	293.14	9.01	3.62	34.60	7.04	36.08	5.70
628-12	5856.20	466.42	62.42	11.90	1313.11	148.79	411.89	66.14	1341.41	195.31	90.68	14.23
628-13	2050.36	223.63	221.01	25.49	2027.14	252.95	295.86	112.10	795.93	316.39	407.72	73.16

	Y (ppm)	± 2SE	Nb (ppm)	± 2SE	Hf (ppm)	± 2SE	Pb 208 (ppm)	± 2SE	Th 232 (ppm)	± 2SE	U238 (ppm)	± 2SE
628-14	5879.87	484.72	134.75	28.26	1451.58	135.41	414.45	34.61	1348.76	74.50	171.40	24.08
628-15	1887.12	121.17	28.19	9.12	3095.21	169.09	69.23	16.66	253.31	55.34	102.16	18.57
	628-Group 1											
628-7	293.33	17.74	1.33	0.46	11346.97	536.57	5.33	1.02	38.13	2.50	97.79	8.77
628-8	290.23	42.27	0.66	0.27	10429.78	662.74	3.88	0.99	25.68	6.18	57.43	8.99
628-10	545.41	37.49	3.40	0.92	9933.42	479.35	3.89	0.88	27.74	2.82	86.01	8.50
	Protolith-aged											
616-41	580.75	49.53	0.21	0.31	8230.43	643.63	11.47	3.47	32.69	4.13	82.35	10.87
616-43	550.56	61.20	2.01	0.82	8738.11	633.47	3.88	1.40	20.25	4.91	43.36	6.53
616-44	704.62	50.66	2.36	0.77	8743.58	903.37	14.10	4.30	37.83	6.22	99.42	13.81
616-45	438.90	35.82	0.67	0.42	9414.72	892.58	7.12	2.14	24.85	4.05	52.62	7.99
616-46	871.76	93.57	1.84	0.89	9684.93	898.89	11.96	3.54	61.92	11.11	109.20	23.42
616-47	1319.42	109.97	1.67	0.79	10353.66	1130.13	33.40	5.98	137.46	24.82	190.36	47.31
616-48	471.73	31.75	1.29	0.70	8938.70	1025.59	5.22	1.92	21.82	5.29	42.70	10.18
616-49	513.88	34.89	1.53	0.72	9447.74	1029.50	3.40	1.83	21.16	5.14	32.57	4.95
616-50	828.76	55.64	2.16	0.70	10532.72	618.74	42.31	8.90	145.28	19.69	204.50	23.75
616-51	339.26	23.34	0.28	0.47	9490.85	547.93	4.44	1.97	20.78	4.56	32.58	5.60
621-2	579.03	22.65	0.97	22.65	8512.10	282.19	10.66	1.37	36.39	1.71	65.91	3.53
621-3	333.40	15.09	0.73	15.09	8335.97	366.70	5.76	0.96	19.22	1.60	30.12	2.08
621-12	563.51	19.76	0.93	19.76	9661.88	332.17	13.23	1.63	38.60	2.28	56.86	3.52
621-14	840.74	32.34	0.09	32.34	9517.80	444.14	11.02	1.48	40.49	3.17	41.11	2.60
621-15	564.93	49.67	0.80	49.67	12229.04	666.25	14.97	1.95	70.32	6.84	146.86	13.60
621-19	439.83	21.87	1.38	21.87	9026.25	284.86	9.93	1.48	28.51	1.89	67.57	3.73
621-23	344.19	26.83	0.91	26.83	8615.25	329.64	4.90	0.86	18.87	1.67	43.28	4.43
621-26	236.68	36.75	0.66	36.75	8541.27	333.92	5.69	0.92	18.87	1.95	38.33	3.46
621-28	329.87	34.71	1.03	34.71	8135.37	304.01	6.86	1.00	21.24	2.15	54.98	5.93
621-30	585.94	27.68	0.83	27.68	8688.96	372.61	8.08	1.30	25.83	2.38	42.84	2.76
621-34	551.14	30.71	1.25	30.71	10809.80	387.99	28.82	2.79	100.90	7.57	113.90	11.52
621-35	146.34	6.66	0.63	6.66	9571.75	476.67	3.58	0.79	9.02	0.91	25.21	1.85
621-36	327.73	16.29	0.51	16.29	9114.03	296.47	5.18	0.94	15.61	1.84	32.35	2.45
621-43	640.41	33.05	1.08	33.05	9132.37	395.24	16.95	1.71	50.70	3.76	108.34	6.55

	Y (ppm)	± 2SE	Nb (ppm)	± 2SE	Hf (ppm)	± 2SE	Pb 208 (ppm)	± 2SE	Th 232 (ppm)	± 2SE	U238 (ppm)	± 2SE
621-49	1097.92	48.67	1.26	48.67	7284.29	335.46	41.69	3.34	129.38	7.16	183.75	10.73
621-53	671.01	37.12	0.72	37.12	8075.10	232.12	9.79	1.39	30.81	2.98	41.59	2.82
621-54	317.33	21.14	0.90	21.14	8931.07	378.74	7.12	1.15	20.14	2.16	41.92	4.51
621-62	314.32	13.00	0.75	13.00	9025.90	399.63	5.12	0.82	16.41	1.37	36.13	2.32
621-63	326.99	13.84	0.37	13.84	8671.22	427.06	4.93	1.09	16.76	1.60	36.11	2.92
621-70	657.55	133.73	0.76	133.73	7593.97	293.12	7.90	1.94	25.35	6.72	35.08	7.60
621-80	336.42	36.92	0.44	36.92	9302.84	410.30	10.11	1.75	30.40	5.70	60.95	9.04
621-84	1293.14	163.48	6.52	163.48	10851.22	528.93	23.05	3.01	285.08	46.15	759.37	107.70
621-87	314.51	12.24	0.53	12.24	9251.49	402.38	4.93	1.05	17.76	1.66	33.34	2.37
621-89	600.21	44.99	1.55	44.99	9183.52	404.22	13.20	1.59	41.90	3.72	82.27	7.47
621-90	697.58	20.23	1.10	20.23	9095.58	371.45	15.37	2.95	41.94	6.50	90.33	12.17
621-91	298.59	11.99	0.40	11.99	11400.82	415.78	13.68	1.29	38.04	2.43	93.12	5.15
621-92	637.14	25.17	0.84	25.17	8610.79	317.10	7.99	1.30	26.75	1.96	37.90	2.80
622-1	494.35	30.86	0.87	0.87	11411.10	907.26	10.37	3.16	28.18	3.54	41.86	6.65
622-2	194.60	13.91	1.12	1.12	15305.52	1261.80	11.27	3.94	33.44	8.94	83.48	14.25
622-5	756.71	157.63	1.24	1.24	11721.74	1328.02	19.61	6.08	80.96	34.65	113.10	40.29
622-9	1275.71	95.74	0.79	0.79	10239.62	1022.24	25.09	5.35	90.24	8.59	120.18	12.74
622-10	408.73	95.20	1.74	1.29	10286.65	1568.38	7.77	15.03	23.08	60.68	63.33	39.64
622-11	509.00	39.49	1.29	1.74	12853.56	1072.34	53.72	2.33	192.15	4.02	152.06	12.74
622-16	1258.21	96.19	1.90	1.90	8895.27	611.91	20.71	2.64	92.87	12.39	137.05	19.69
622-17	263.86	16.81	1.49	1.49	11418.83	923.04	5.37	2.44	18.30	3.86	38.40	7.82
622-28	186.18	50.28	0.87	1.23	14842.01	956.62	10.01	2.12	45.84	6.62	141.04	10.85
622-29	131.30	13.52	1.36	0.87	15302.97	1722.04	10.22	2.92	40.86	6.65	111.19	19.13
622-30	421.63	8.68	1.23	1.36	10195.86	1644.52	5.65	2.15	27.22	6.64	60.58	15.79

Appendix F: Whole Rock Geochemistry

See Section 3.4 for methodology.

Analyte	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃ (T)	MnO	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂	P ₂ O ₅	LOI	Total
Unit	%	%	%	%	%	%	%	%	%	%	%	%
Analysis Method	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	FUS-ICP	GRAV	FUS-ICP
DC944601	64.76	15.36	5.8	0.107	1.55	5.17	3.65	0.51	0.497	0.1	2.76	100.3
DC944602	67.02	16.28	3.84	0.057	1.13	3.88	2.85	1.97	0.48	0.07	2	99.58
DC944603	63.77	14.53	5.51	0.075	1.86	5.64	2.02	2	0.464	0.11	3.75	99.72
DC944604	63.87	16.77	5.48	0.054	1.89	3.78	4.83	0.59	0.479	0.08	2.31	100.1
DC944605	62.34	15.65	9.01	0.115	0.85	3.91	4.06	0.56	0.477	0.1	2.38	99.44
DC944606	65.61	15.44	5.42	0.067	1.57	4.89	2.7	1.84	0.463	0.09	2.19	100.3
DC944607	64.85	16.48	5.07	0.061	1.84	4.13	4.3	1.03	0.494	0.09	1.82	100.2
DC944608	64.19	16.62	6.1	0.068	1.63	2.12	6.3	1.01	0.612	0.18	1.36	100.2
DC944609	59.04	15.59	5.61	0.067	1.61	5.76	2.55	2.3	0.46	0.09	5.38	98.47
DC944610	64.07	15.07	4.53	0.056	1.35	4.36	2.78	2.39	0.445	0.1	4.78	99.94
DC944611	63.27	14.85	3.58	0.078	1.56	4.54	1.96	3.06	0.536	0.16	5.77	99.35
DC944612	64.14	16.9	5.19	0.059	1.42	4.23	3.7	1.57	0.532	0.21	1.49	99.44
DC944613	63.49	16.05	5.14	0.161	0.84	5	3.04	2.12	0.466	0.17	4.1	100.6
DC944614	62.95	15.08	5.63	0.131	1.01	4.84	2.22	2.85	0.431	0.09	5.5	100.7
DC944615	66.19	16.15	5.31	0.097	0.75	3.82	4.3	1.07	0.457	0.09	1.55	99.79
DC944616	66.04	16.25	5.51	0.068	1.47	4.25	3.4	1.21	0.498	0.22	1.71	100.6
DC944617	54.74	15.01	7.92	0.12	2.65	7.28	2.3	2.19	0.794	0.12	6.62	99.75
DC944618	61.53	13.88	5.66	0.089	1.78	5.31	2.19	1.88	0.637	0.14	6.13	99.22
DC944619	85.22	6.44	2.42	0.029	0.28	1.01	0.48	1.34	0.163	0.05	1.82	99.26
DC944620	64.78	15.88	4.23	0.059	1.14	2.98	1.41	3	0.468	0.11	4.66	98.71
DC944621	78.36	9.78	3.6	0.039	0.57	1.25	0.36	2.59	0.324	0.07	3.46	100.4
DC944622	96.22	0.89	1.51	0.025	0.23	0.68	0.07	0.01	0.015	0.02	0.6	100.3
DC944623	62.54	14.12	6.47	0.089	1.78	4.77	1.22	3.52	0.758	0.17	3.26	98.68
DC944624	72.03	12.61	4.47	0.079	1.09	2.26	0.78	2.85	0.401	0.15	3.39	100.1

Analyte	SiO2	Al2O3	Fe2O3(T)	MnO	MgO	CaO	Na2O	K2O	TiO2	P2O5	LOI	Total
DC944625	78.33	9.81	3.34	0.034	0.43	1.21	0.43	2.6	0.308	0.11	2.86	99.46
SG260	62.13	19.57	3.83	0.047	0.9	1.9	1	4.87	0.63	0.07	3.96	98.91
SG261	42.89	11.37	8.96	0.134	10.14	8.08	0.83	0.82	0.713	0.32	14.21	98.47
SG262	60.31	16.01	5.06	0.068	1.51	4.6	0.91	3.59	0.49	0.16	5.71	98.44
SG263	62.66	17.81	5.58	0.013	0.58	1.17	0.91	4.16	0.532	0.09	5.06	98.57
SG264	70.38	13.07	4.23	0.039	1.51	2.45	1.08	2.62	0.419	0.18	4.25	100.2
SG265	45.5	14.84	14.17	0.082	2.71	3.64	0.37	3.99	1.586	0.11	11.83	98.83
SG266	61.97	17.4	4.32	0.058	1.58	4.2	3.01	2.08	0.582	0.2	3.88	99.29
SG628	1.43	0.43	3.64	1.249	1.47	48.79	0.09	0.23	0.662	0.04	40.11	98.14

Analyte	Au	Ag	As	Ba	Be	Bi	Br	Cd	Co	Cr	Cs	Cu
Unit	ppb	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Analysis Method	INAA	MULT INAA / TD-ICP	INAA	FUS-ICP	FUS-ICP	FUS-MS	INAA	TD-ICP	INAA	INAA	FUS-MS	TD-ICP
DC944601	12	< 0.5	< 1	161	< 1	< 0.1	< 0.5	< 0.5	17.8	27.3	1	82
DC944602	15	< 0.5	3	424	< 1	< 0.1	< 0.5	< 0.5	9.7	30.7	2.3	32
DC944603	891	0.5	16	191	< 1	0.2	< 0.5	< 0.5	20.9	36.4	2.9	41
DC944604	< 1	< 0.5	< 1	182	< 1	< 0.1	< 0.5	< 0.5	23.4	25	0.7	97
DC944605	14	< 0.5	< 1	227	< 1	< 0.1	< 0.5	< 0.5	15.2	27.8	1.1	24
DC944606	35	< 0.5	2	257	< 1	< 0.1	7.5	< 0.5	13.5	15.9	1.6	46
DC944607	2	< 0.5	< 1	340	1	< 0.1	< 0.5	< 0.5	15.8	31.3	1.8	1
DC944608	206	0.8	4	152	< 1	< 0.1	< 0.5	< 0.5	32.5	54.5	1.2	168
DC944609	860	0.7	8	286	< 1	< 0.1	131	< 0.5	14.4	17	1.5	63
DC944610	844	1.5	49	229	< 1	< 0.1	< 0.5	< 0.5	15.6	24.4	2.1	22
DC944611	482	0.6	20	319	< 1	< 0.1	< 0.5	< 0.5	7.5	17.6	2	123
DC944612	11	< 0.5	2	296	< 1	< 0.1	6.1	< 0.5	11.8	22.2	1.4	11
DC944613	78	< 0.5	6	199	< 1	< 0.1	< 0.5	< 0.5	11.2	19.6	1.3	37
DC944614	569	0.5	26	260	< 1	< 0.1	< 0.5	< 0.5	11.4	24.8	1.4	53
DC944615	6	< 0.5	< 1	237	< 1	< 0.1	< 0.5	< 0.5	13	21.7	1.5	34

Analyte	Au	Ag	As	Ba	Be	Bi	Br	Cd	Co	Cr	Cs	Cu
DC944616	< 1	< 0.5	< 1	290	< 1	< 0.1	15.1	< 0.5	11.2	25.9	1	< 1
DC944617	475	0.8	30	180	< 1	< 0.1	< 0.5	< 0.5	25.1	56.4	2.2	90
DC944618	532	0.9	62	125	1	< 0.1	< 0.5	< 0.5	14.9	15.5	1.3	19
DC944619	1120	< 0.5	39	126	< 1	< 0.1	< 0.5	< 0.5	4.9	30.8	1	8
DC944620	994	0.6	55	252	< 1	< 0.1	< 0.5	< 0.5	11.5	22.8	2.2	27
DC944621	20200	6.5	38	247	< 1	0.2	< 0.5	< 0.5	7.2	32.7	1.5	4
DC944622	69	< 0.5	5	3	< 1	< 0.1	17.2	< 0.5	0.1	20.6	0.1	9
DC944623	4080	2.3	12	196	1	< 0.1	15	< 0.5	14.8	19	2.1	3
DC944624	2610	2.1	70	221	< 1	< 0.1	3.5	< 0.5	10.8	28.7	1.7	87
DC944625	13300	4	43	194	< 1	< 0.1	< 0.5	< 0.5	6.8	12.7	1	2
SG260	56	< 0.5	17	411	1	< 0.1	< 0.5	< 0.5	13.1	34.2	3.6	23
SG261	56	< 0.5	< 1	530	1	< 0.1	< 0.5	< 0.5	39.1	820	0.8	2
SG262	364	< 0.5	23	367	< 1	< 0.1	1.6	< 0.5	14.4	18.2	1.6	84
SG263	> 30000	9.4	50	317	1	< 0.1	< 0.5	< 0.5	15.6	21.8	2.9	45
SG264	958	0.7	23	344	1	0.1	< 0.5	< 0.5	14.4	19.1	1.9	49
SG265	> 30000	14.8	205	285	1	0.2	< 0.5	< 0.5	55.3	121	2.6	72
SG266	54	0.5	8	357	1	< 0.1	14.8	< 0.5	9.1	18.3	1.7	7
SG628	10	3.8	< 1	219	< 1	< 0.1	6.7	1.4	6.4	14.4	1	19

Analyte	Ga	Ge	Hf	In	Ir	Mo	Nb	Ni	Pb	Rb	S	Sb
Unit	ppm	ppm	ppm	ppm	ppb	ppm	ppm	ppm	ppm	ppm	%	ppm
Analysis Method	FUS-MS	FUS-MS	FUS-MS	FUS-MS	INAA	FUS-MS	FUS-MS	TD-ICP	TD-ICP	FUS-MS	TD-ICP	INAA
DC944601	17	0.6	2.3	< 0.1	< 1	< 2	2	31	< 5	13	0.018	< 0.1
DC944602	18	0.7	2.7	< 0.1	< 1	< 2	2.4	27	< 5	34	0.183	< 0.1
DC944603	16	0.7	2.1	< 0.1	< 1	< 2	1.9	38	< 5	36	1.21	0.1
DC944604	19	0.7	2.4	< 0.1	< 1	< 2	2.1	44	< 5	13	0.02	0.2
DC944605	19	0.5	2.5	< 0.1	< 1	< 2	2.2	34	< 5	13	0.103	< 0.1
DC944606	18	0.6	2.3	< 0.1	< 1	< 2	1.7	20	< 5	36	0.1	< 0.1

Analyte	Ga	Ge	Hf	In	Ir	Mo	Nb	Ni	Pb	Rb	S	Sb
DC944607	18	0.6	2.5	< 0.1	< 1	< 2	2.3	27	< 5	23	0.005	< 0.1
DC944608	19	0.5	2.6	< 0.1	< 1	< 2	3.1	51	< 5	16	0.966	< 0.1
DC944609	18	0.9	2.2	< 0.1	< 1	< 2	1.9	27	< 5	38	0.827	< 0.1
DC944610	19	1	2.6	< 0.1	< 1	< 2	2.5	25	6	42	2.28	0.1
DC944611	18	0.9	2.6	< 0.1	< 1	< 2	3	12	< 5	47	0.953	0.1
DC944612	19	0.7	2.9	< 0.1	< 1	< 2	2.9	22	< 5	25	0.079	< 0.1
DC944613	17	0.8	2.5	< 0.1	< 1	< 2	2.6	19	5	34	0.513	< 0.1
DC944614	17	0.9	2.5	< 0.1	< 1	< 2	2.4	25	< 5	46	1.18	< 0.1
DC944615	19	0.8	2.8	< 0.1	< 1	< 2	2.6	24	< 5	22	0.014	< 0.1
DC944616	18	0.7	2.8	< 0.1	< 1	< 2	2.7	21	< 5	28	0.018	< 0.1
DC944617	16	0.9	2.4	< 0.1	< 1	< 2	2.4	39	< 5	35	1.22	0.2
DC944618	16	1	2.4	< 0.1	< 1	< 2	3.2	15	< 5	31	2.63	0.2
DC944619	9	2.3	0.9	< 0.1	< 1	< 2	0.9	8	< 5	26	0.964	0.2
DC944620	21	1.6	2.7	< 0.1	< 1	< 2	2.7	14	< 5	56	1.84	0.3
DC944621	13	2.1	1.5	< 0.1	< 1	< 2	1.3	14	< 5	49	1.65	< 0.1
DC944622	1	1.2	< 0.1	< 0.1	< 1	< 2	< 0.2	5	< 5	< 1	0.036	< 0.1
DC944623	21	1.6	2.9	< 0.1	< 1	< 2	4.8	9	< 5	66	2.66	0.3
DC944624	18	1.5	2.3	< 0.1	< 1	2	2.2	13	8	52	1.79	0.3
DC944625	16	1.7	1.7	< 0.1	< 1	< 2	1.9	13	8	46	1.6	0.1
SG260	25	1.7	4.1	< 0.1	< 1	< 2	4.7	28	< 5	98	0.212	0.2
SG261	17	1.3	3.5	< 0.1	< 1	< 2	6.7	274	< 5	20	0.002	0.6
SG262	21	1	3.1	< 0.1	< 1	< 2	4.3	17	< 5	60	1.31	0.2
SG263	27	1.7	4.2	< 0.1	< 1	< 2	5.5	25	< 5	78	3.26	0.2
SG264	18	1.3	2.6	< 0.1	< 1	< 2	2.7	16	< 5	51	1.63	< 0.1
SG265	26	1.6	2.6	0.1	< 1	< 2	3.3	72	< 5	74	9.18	0.5
SG266	23	0.9	4.4	< 0.1	< 1	< 2	5.8	13	< 5	50	0.365	< 0.1
SG628	2	< 0.5	< 0.1	0.1	< 1	< 2	36.6	3	14	9	0.016	< 0.1

Analyte	Sc	Se	Sn	Sr	Ta	Th	U	V	W	Y	Zn	Zr
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Analysis Method	INAA	INAA	FUS-MS	FUS-ICP	FUS-MS	FUS-MS	FUS-MS	FUS-ICP	INAA	FUS-ICP	MULT INAA / TD-ICP	FUS-ICP
DC944601	9.94	< 0.5	< 1	296	0.2	2.27	0.53	82	< 1	10	71	106
DC944602	8.69	< 0.5	1	287	0.24	3.02	0.71	74	2	7	52	122
DC944603	9.94	< 0.5	1	230	0.17	1.79	0.41	81	3	8	72	101
DC944604	10	< 0.5	< 1	261	0.22	2.05	0.48	82	< 1	7	76	104
DC944605	13.6	< 0.5	< 1	194	0.22	2.05	0.5	95	< 1	9	112	106
DC944606	8.41	< 0.5	< 1	207	0.16	1.84	0.31	69	< 1	7	64	100
DC944607	9.77	< 0.5	< 1	318	0.23	2.11	0.52	84	< 1	8	66	110
DC944608	11.9	< 0.5	< 1	158	0.28	2.64	0.56	104	< 1	10	48	118
DC944609	9.6	< 0.5	< 1	245	0.2	1.91	0.43	81	14	7	38	95
DC944610	8.81	< 0.5	< 1	150	0.24	2.94	0.72	73	10	7	38	117
DC944611	8.07	< 0.5	< 1	246	0.24	1.92	0.49	75	12	8	51	117
DC944612	8.33	< 0.5	1	265	0.26	3	0.73	83	1	11	60	142
DC944613	7.29	< 0.5	< 1	242	0.28	2.68	0.65	72	5	10	46	121
DC944614	7.5	< 0.5	< 1	187	0.25	2.87	0.65	71	17	9	61	116
DC944615	7.76	< 0.5	< 1	225	0.29	3.28	0.73	74	< 1	8	81	119
DC944616	7.91	< 0.5	1	340	0.28	2.88	0.72	85	< 1	10	75	126
DC944617	16.5	< 0.5	< 1	215	0.18	1.72	0.4	151	12	15	106	105
DC944618	9.62	< 0.5	< 1	273	0.26	1.56	0.39	100	19	10	108	112
DC944619	3.57	< 0.5	< 1	87	0.12	1.17	0.31	30	< 1	2	54	40
DC944620	7.48	< 0.5	< 1	265	0.24	1.89	0.48	68	5	7	56	120
DC944621	5.97	< 0.5	< 1	88	0.14	1.73	0.36	52	15	8	33	65
DC944622	0.3	< 0.5	< 1	15	< 0.01	< 0.05	0.01	8	< 1	2	21	4
DC944623	12.2	< 0.5	1	255	0.39	1.61	0.45	116	45	14	36	136
DC944624	6.76	< 0.5	< 1	184	0.22	1.84	0.44	61	487	9	45	108
DC944625	4.89	< 0.5	< 1	102	0.19	1.54	0.41	50	2120	6	25	82
SG260	11.9	< 0.5	1	186	0.45	3.53	0.79	100	4	9	59	164
SG261	18	< 0.5	1	350	0.34	6.81	1.23	138	17	13	161	150
SG262	7.9	< 0.5	1	166	0.34	2.25	0.61	69	54	13	32	151

Analyte	Sc	Se	Sn	Sr	Ta	Th	U	V	W	Y	Zn	Zr
SG263	8.42	< 0.5	1	194	0.5	3.51	0.8	86	96	11	44	183
SG264	6.59	< 0.5	1	159	0.28	2.22	0.58	59	35	7	38	119
SG265	34.2	< 0.5	1	129	0.25	0.9	0.32	341	350	25	54	99
SG266	9.32	< 0.5	1	196	0.43	3.03	0.71	73	8	12	58	179
SG628	7.66	< 0.5	< 1	7928	2.55	0.58	0.14	15	< 1	64	27	3

Analyte	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tl	Tm	Yb	Lu
Unit	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Analysis Method	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS	FUS-MS
DC944601	14.3	28.5	3.29	12.8	2.44	0.691	2.01	0.33	1.85	0.37	1.04	< 0.05	0.153	1.02	0.165
DC944602	16.4	31.2	3.56	13.6	2.67	0.658	2	0.31	1.68	0.3	0.88	0.11	0.133	0.82	0.129
DC944603	12.1	23.8	2.81	10.9	2.2	0.599	1.69	0.26	1.55	0.28	0.82	0.14	0.117	0.77	0.119
DC944604	13	25.4	2.95	11.6	2.13	0.626	1.89	0.28	1.59	0.3	0.83	0.08	0.129	0.82	0.134
DC944605	14.1	27.4	3.18	12.4	2.42	0.737	2	0.32	1.86	0.38	1.08	< 0.05	0.162	1.09	0.175
DC944606	10.7	21.2	2.53	9.99	2.18	0.605	1.71	0.27	1.46	0.28	0.83	0.16	0.111	0.72	0.117
DC944607	14.2	27.4	3.21	12.6	2.41	0.666	1.86	0.29	1.6	0.31	0.89	< 0.05	0.129	0.83	0.131
DC944608	22.3	45.7	5.35	20.6	3.69	0.998	2.65	0.38	2.04	0.38	1.07	< 0.05	0.149	0.93	0.149
DC944609	13.7	26.5	3.08	12.1	2.43	0.755	1.91	0.28	1.5	0.3	0.81	0.08	0.122	0.86	0.135
DC944610	16.1	30.4	3.43	12.8	2.36	0.658	1.74	0.27	1.5	0.29	0.84	0.12	0.123	0.85	0.132
DC944611	15.8	32.9	3.88	15.2	2.58	0.683	2	0.3	1.7	0.32	0.89	0.11	0.129	0.84	0.131
DC944612	24.4	51.1	6.18	23.9	4.29	1.08	2.81	0.38	2.08	0.38	1.03	0.07	0.147	0.91	0.155
DC944613	19	38.9	4.62	18.2	3.14	0.852	2.34	0.33	1.77	0.33	0.92	0.08	0.134	0.87	0.141
DC944614	16	29.8	3.33	12.8	2.45	0.731	1.87	0.3	1.74	0.33	0.94	0.08	0.137	0.89	0.146
DC944615	17.3	33	3.58	13.8	2.6	0.734	2.01	0.3	1.77	0.33	0.98	< 0.05	0.134	0.85	0.135
DC944616	23.5	48.4	5.89	23.1	4.14	1.25	2.72	0.39	2.06	0.4	1.07	0.06	0.149	0.95	0.149
DC944617	12.1	24.5	2.95	12.1	2.52	0.765	2.48	0.43	2.64	0.54	1.62	0.09	0.236	1.59	0.247
DC944618	13.6	28.3	3.4	13.8	2.76	0.796	2.29	0.36	2.18	0.41	1.19	0.07	0.175	1.13	0.174
DC944619	7.19	14.2	1.63	5.9	1.13	0.276	0.85	0.1	0.55	0.1	0.28	0.06	0.039	0.26	0.044
DC944620	14.2	27.9	3.17	11.7	1.94	0.631	1.58	0.23	1.38	0.26	0.74	0.12	0.111	0.69	0.102
DC944621	11.4	23.5	2.71	10.3	1.81	0.462	1.41	0.2	1.18	0.22	0.65	0.14	0.092	0.59	0.099
DC944622	0.56	1.16	0.14	0.48	0.07	0.03	0.1	0.02	0.1	0.02	0.05	< 0.05	< 0.005	0.03	0.009

Analyte	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tl	Tm	Yb	Lu
DC944623	14	30.3	3.57	15	2.86	0.849	2.63	0.43	2.53	0.49	1.38	0.15	0.194	1.22	0.188
DC944624	16.9	35.1	4.06	15.5	2.51	0.788	1.7	0.25	1.45	0.26	0.73	0.14	0.104	0.71	0.108
DC944625	12.5	26.5	3.11	11.2	2.07	0.502	1.46	0.21	1.05	0.19	0.55	0.13	0.08	0.51	0.083
SG260	23.5	47.1	5.49	20.2	3.37	0.997	2.7	0.38	2.08	0.39	1.07	0.34	0.159	1.05	0.166
SG261	51.3	104	11.7	41.9	6.16	1.87	4.16	0.53	2.59	0.46	1.24	0.07	0.165	1.07	0.169
SG262	22.6	45.1	5.19	20.8	3.5	0.981	2.58	0.38	2.14	0.42	1.15	0.16	0.165	1.11	0.174
SG263	28.4	58.8	6.77	25.7	4.13	1.17	2.75	0.39	2.19	0.41	1.2	0.24	0.183	1.25	0.197
SG264	17.7	38.2	4.48	16.4	2.89	0.695	2	0.25	1.34	0.26	0.75	0.15	0.112	0.74	0.12
SG265	7.32	16.5	2.15	9.9	2.5	0.715	2.96	0.56	3.83	0.87	2.81	0.16	0.427	2.75	0.416
SG266	26.7	55.8	6.54	23.5	4	1.11	2.98	0.4	2.11	0.4	1.09	0.17	0.149	0.98	0.168
SG628	113	263	31.2	111	16.8	4.52	13.1	1.87	11.6	2.35	7.23	0.08	1.09	7.52	1.19