

G-Chron 2021 – Round 2

— An International Proficiency Test for U-Pb Geochronology Laboratories — Report on the 2021 Round of G-Chron based on Archean Zircon Kara-18 (Distribution: September 2021)

Michael Wiedenbeck¹, Peter C. Webb², Johannes Glodny¹, Thomas C. Meisel³

¹Deutsches GeoForschungsZentrum GFZ, Telegrafenberg, 14473 Potsdam, Germany.

²Formerly of the Department of Environment, Earth and Ecosystems, The Open University,
Walton Hall, Milton Keynes, MK7 6AA, UK.

³General and Analytical Chemistry, Montanuniversität Leoben, 8700 Leoben, Austria.

Proficiency testing (PT) is one of the few means for an analytical laboratory to assess its data quality under routine operating conditions. Here we report the results of Round #2 of the G-Chron PT programme, which is sponsored by the International Association of Geoanalysts (IAG). G-Chron is the first PT scheme devoted to the U-Pb dating of minerals, primarily zircon, in geological materials. In this second round of G-Chron a total of 67 geochronology laboratories received the test material “Kara-18”, which previously had been characterized by three isotope dilution TIMS laboratories. A total of 50 of the participating laboratories reported data by the 19 January 2022 deadline. Here we report the submitted measurement results along with their related performance assessments. Our analysis provides a means for the participating laboratories to assess their individual performance against the experimental fitness-for-purpose criteria proposed by the scheme’s organisers. This PT scheme also provides laboratories active in the area of U-Pb zircon dating a compilation of the data quality produced by their peer community.

Introduction

In the Earth Sciences the understanding of timing and rates of geological events and processes is of paramount importance. Such information is commonly derived using radioactive decay systems. Due to the resistance of zircon to chemical alteration and its propensity to incorporate significant amounts of uranium and thorium into its crystal structure, while largely excluding the incorporation of lead at the time of crystallization, zircon is perhaps the most widely analysed mineral phase for defining the timing of igneous or metamorphic events. However, until now there has been scant information about the overall quality of this ever-expanding dataset. It is anticipated that this PT programme will provide information about the quality of the measurement processes employed by the participating laboratories. Ages based on the ^{238}U - ^{206}Pb radioactive decay system are commonly reported with associated precisions ranging from less than $\pm 0.1\%$ (isotope dilution, 1SE) to $\pm 1\%$ (*in situ* methods, 1SE). The intent of the G-Chron PT scheme is to provide participating laboratories an opportunity to test for both unrecognized bias in their age results and to provide information on the reliability of the assigned uncertainty estimations. In circumstances where results submitted are shown to be unsatisfactory, it is recommended that those participating laboratories should investigate their measurement procedures to identify unsuspected sources of measurement bias in their results or overlooked components in their uncertainty budget, allowing them to take corrective actions where warranted.

The Organisation of G-Chron and its Scheduling in 2021

Having already established PT schemes in bulk geochemical analysis and microanalysis, namely the GeoPT and G-Probe programmes respectively, the governing Council of the IAG voted in March 2015 to launch a PT scheme devoted principally to U-Pb zircon geochronology. The intention of this initiative was to

identify PT test materials consisting of concordant, homogeneous zircon. These test materials would be assigned ages based on U-(Th)-Pb isotope dilution results from several TIMS laboratories that had previously proven performance capabilities. Suitable material was to be identified, either from scientific publications or from other information sources, and the initial homogeneity testing of candidate zircon populations would be evaluated by Secondary Ion Mass Spectrometry (SIMS). It was intended that the G-Chron PT programme would distribute a single test sample per year. Left-over materials would subsequently be made available to the geoanalytical community. It was agreed that other phases besides zircon could be included as supplementary materials on a case-by-case basis during future rounds.

The first round of G-Chron took place in 2019 and the results were reported in April 2020. Round #2 followed a similar pattern except that some details now were requested in a manner that aimed to avoid any ambiguity; in addition to age results and age uncertainties, isotope ratios and their uncertainties were also invited to be submitted.

Due to disruptions that many laboratories experienced due to the Covid-19 pandemic, the second round of the G-chron programme was delayed by a year, resulting in on-line registration for new participants to join in Round #2 only beginning in June 2021. The Kara-18 zircon test material was dispatched to participants at the end of August, with each participant receiving a 0.5 ml screw-top plastic vial that contained a ~ 90 mg split of nearly pure zircon with a grain size ≤ 1 mm; it was supplied in a Ziploc® plastic bag and labelled “Kara-18 Zircon”. A one-page set of instructions accompanying the test material provided information about the material and the method for submitting results on-line. The deadline for data submission was initially set for 15 December 2021, but was subsequently extended to 19 January 2022.

In November 2021 the www.gchron.info website was opened for on-line data submission, enabling participants to submit their results. Laboratories were required to provide $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ ages and their associated uncertainties expressed at the 68% confidence level. As an addition to the scheme’s first round, participants were also invited to report radiogenic isotope ratios and associated uncertainties for both the $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ age results. No Th-Pb TIMS data were available for the Kara-18 material, meaning that no TIMS-defined target age is available for this chronometer. Nonetheless $^{208}\text{Pb}/^{232}\text{Th}$ ages and radiogenic isotope ratios and their associated uncertainties could be reported, allowing the participating labs to compare their Th-Pb results to those reported by other laboratories. All age values were to be reported in units of Ma (millions of years) with at least one digit to the right of decimal point to be included. Furthermore, analysts were asked to provide metadata on key aspects of their procedures. All laboratories that registered to take part in this round of G-Chron are eligible to download this report from the G-Chron website when it becomes available in mid-2022.

Origin and Description of the Test Material

The starting material for Kara-18 was sampled from a large granitic pluton located in the Murchison Province of the Yilgarn Craton of Western Australia. Similar material had been dated by ion microprobe as reported by Wiedenbeck and Watson (1993) for Geological Survey of Western Australia sample number 83407. Those data indicated a concordant, mostly homogeneous U-Pb system for which a $^{206}\text{Pb}/^{238}\text{U}$ age of 2641 ± 5 Ma (1SE) was reported. The sampling location for GSWA #83407 is only approximately known, but it is likely to be *circa* 1.4 km ESE of the collection site for Kara-18. The texture and mineralogy of the rock at the two localities are very similar and it is highly likely they both represent the same pluton.

The Kara-18 starting material was collected from a low, rounded outcrop extending over a distance of a few hundred metres that is surrounded by silcrete and scrub vegetation. The exact sampling locality was restricted to a roughly 20 x 20 metre area where the rock outcrop contained large fractures which readily allowed sampling with sledgehammers and chisels. The material is universally stained to a rust colour, though the interiors of hand samples appear to be mostly fresh. The site is *circa* 500 meters east of a dirt track and is some 1.3 km NNE of Karara Station. Sampling took place in July 2018, at which time 310 kg of rock was collected and subsequently transported to Potsdam, Germany for processing. The name Kara-18 is derived from the proximity to the nearest geographic feature (Karara Station) and the year of sampling.

Preparation of the Test Material

The material was crushed using a jaw crusher followed by further grain size reduction using a roll mill and sieving, resulting in a < 1 mm grain-size sieve fraction. Zircons were concentrated using a Wilfley table, followed by Frantz magnetic separation operating at 1.5 A current and a side tilt of 10°. Further enrichment of zircon involved using three passes through the heavy liquid methylene iodide. Under a binocular microscope the resulting material was found to be largely dust-free and to consist of ca. 98% zircon; these crystals are mostly elongate and euhedral in morphology with a clear, slightly pink hue, with lengths mostly less than 300 µm. Both mineral inclusions and fractures are visible in many grains, as typical of many real-world samples, making Kara-18 well-suited for use as a test sample within this PT scheme. At the end of this entire procedure 47.4 grams of zircon were recovered. Finally, a riffle splitter was used to prepare the individual units of material for use in both the ID-TIMS characterization and the G-Chron Round #2 Proficiency Test. A single unit consists of *circa* 90 mg of zircon that was placed in a screw top plastic vial.

SIMS Homogeneity Testing

Homogeneity testing of Kara-18 material started with mounting numerous zircon grains from a single split of material. A 25.4 mm diameter, well-polished epoxy disk was prepared along with the 91500 and Temora2 zircon calibration materials. U-Th-Pb determinations on this mount were conducted using the Potsdam Cameca 1280-HR SIMS instrument. A total of 35 isotope ratio measurements were conducted. In order to have an unbiased picture of the Kara-18 zircon population this was done by selecting random locations on a total of 23 grains without any advanced imaging information. Subsequent observations on each crater using a reflected light microscope identified a total of 11 locations that included either visible cracks or contained visible mineral inclusions. The remaining 24 results formed a tight cluster on a Concordia plot that is consistent with a homogeneous population exhibiting little to no Pb-loss (Figure A, Panel A). These SIMS determinations were calibrated with the 91500 zircon reference material, which has an assigned $^{206}\text{Pb}/^{238}\text{U}$ age of 1062.4 Ma (Wiedenbeck et al. 1995). We also assessed this data set for the homogeneity of its Th-Pb system. The radiogenic $^{208}\text{Pb}/^{232}\text{Th}$ ratios for those same 24 measurement results also indicated that no detectable Pb-loss has affected this geochronometer (Figure A, Panel B). Our SIMS data for this cluster gave the following unweighted mean ages for n = 24 results as based on the decay constants recommended by Steiger and Jäger (1977):

$^{206}\text{Pb}/^{238}\text{U}$ age:	2635.2 Ma
$^{207}\text{Pb}/^{206}\text{Pb}$ age:	2631.4 Ma
$^{208}\text{Pb}/^{232}\text{Th}$ age:	2627.7 Ma

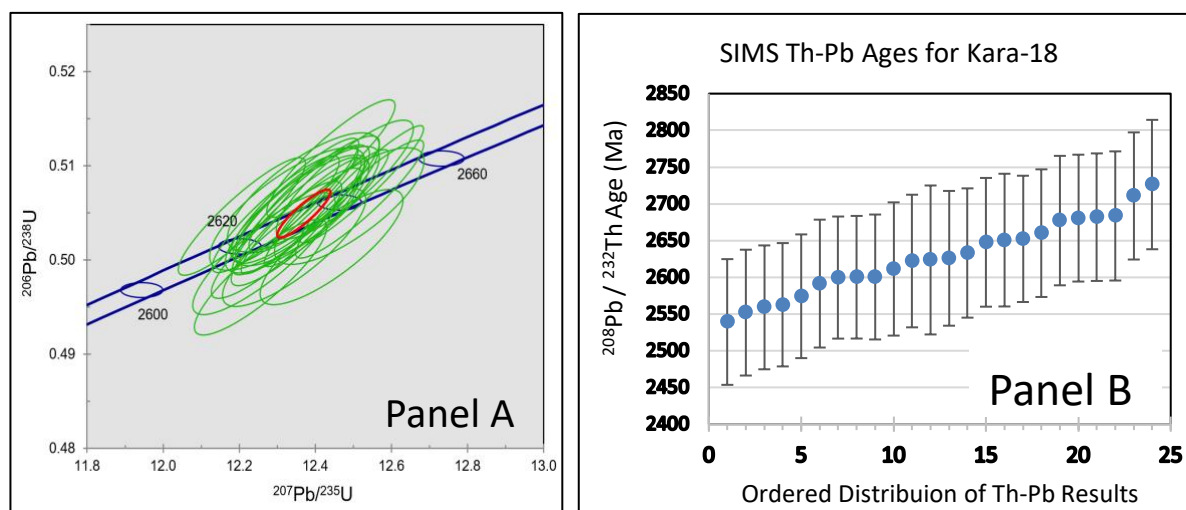


Figure A: Results from SIMS homogeneity testing for the Kara-18 zircon material. These are for the 24 random locations that were free of cracks and inclusions. (Panel A) U-Pb Concordia plot for the data obtained from the Potsdam SIMS instrument. The green ellipses represent the 68% confidence interval of the individual results and the red ellipse is the 1SE confidence interval of the mean of that population. The Concordia curve is based on the decay constants and the $^{238}\text{U}/^{235}\text{U}$ ratio recommended by Steiger and Jäger (1977) and the width of the curve indicates the decay constant uncertainties. Age labels are in Ma. (Panel B) Ordered distribution plot for the $^{208}\text{Pb}/^{232}\text{Th}$ ages from the same 24 SIMS measurement results with uncertainty bars representing the 1SE precision estimates for each individual result.

As this material was deemed well-suited for use in a U-Pb PT programme, three established isotope dilution thermal ionization mass spectrometry (ID-TIMS) laboratories were recruited to provide data that would be used to assign the $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ target ages for this proficiency test.

Derivation of the Assigned (Target) Age Values

The three ID-TIMS laboratories that volunteered to provide data for this project were at Boise State University, at the Canadian Geological Survey in Ottawa and at the Technical University of Freiberg. They provided a total of 16 ID-TIMS results of which 14 involved a chemical abrasion (CA) pre-treatment and 2 made use of mechanically abraded single grains; these data are shown on a conventional Concordia plot in Figure B. Although the data distribution is larger than the indicated uncertainty estimates, these 16 results still point to a material that is well-suited for use in this G-Chron proficiency testing scheme. An additional 3 ID-TIMS determinations based on a more gentle acid washing pre-treatment were also provided by Ottawa. The most extreme of these suggests as much as 28% Pb-loss from the system, though this may also reflect a component related to the widespread presence of inclusions in this material. For the purposes of this proficiency test, the $n = 16$ results based on chemically or mechanically abraded grains were used to define the target value for the $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ chronometers. We have elected to use the robust means from this data set, leading to the following target ages and their associated 68% confidence intervals:

$^{206}\text{Pb}/^{238}\text{Pb}$ age: 2628.38 +/- 0.95 Ma

$^{207}\text{Pb}/^{206}\text{Pb}$ age: 2632.52 +/- 0.56 Ma

All of these data will be presented in a subsequent manuscript providing a detailed characterization of the Kara-18 zircon U-Pb system, after which it is intended that the Kara-18 material will be made available to the global geochemical community.

Due to the very limited number of ID-TIMS facilities with the necessary expertise in the art of Th-Pb measurement, it was not possible to obtain TIMS results for the Kara-18 material. We are therefore unable to provide a target age for this system.

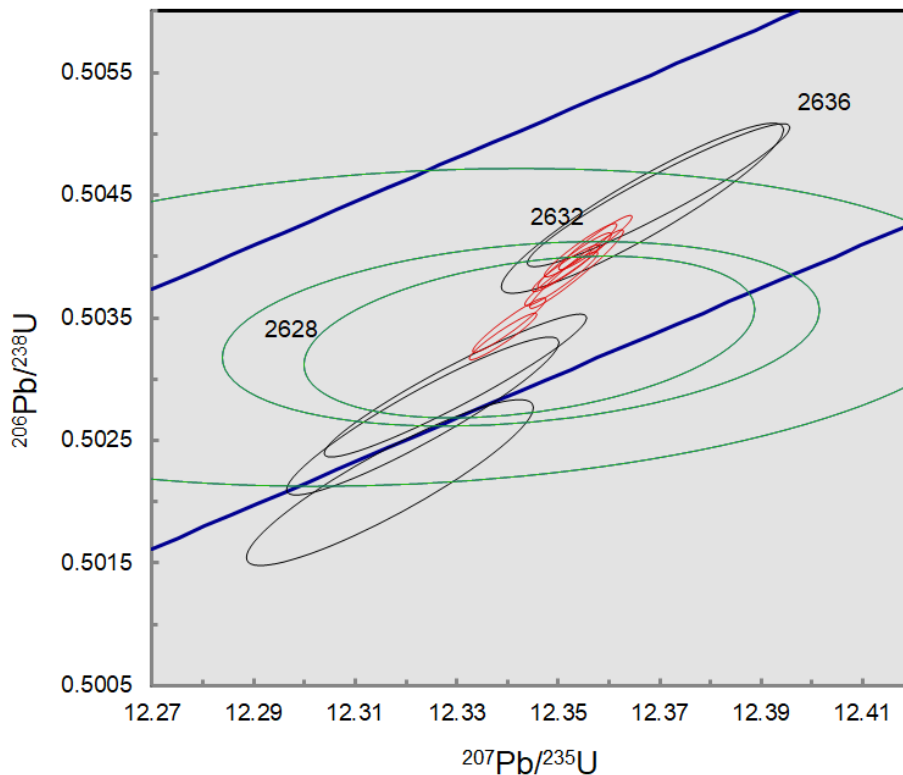


Figure B: U-Pb Concordia plot for 16 determinations on chemically abraded material employing isotope dilution as reported by three independent TIMS laboratories. The colours are: red = Boise State, green = Technische Universität Bergakademie Freiberg, black = Geological Survey of Canada. Uncertainty estimates are enlarged to 95% confidence level in order to make the data visually more clear. The blue lines represent the upper and lower bounds for the Concordia based on 95% confidence level derived from the decay constant uncertainties and the numbers indicate in Ma the age on the Concordia curve.

Submission of Results

Participants were asked to submit results obtained using their routine procedures, which is a fundamental requirement of a proficiency testing programme. In a change from the G-Chron Round #1 proficiency test, for Kara-18 it was requested that each participating laboratory should report both its determined age and its radiogenic isotope ratio for both the $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ chronometers. Although no target value had been established for the Th-Pb chronometer, the participating laboratories were nonetheless given the option of reporting both their $^{208}\text{Pb}/^{232}\text{Th}$ age and their $^{208}\text{Pb}/^{232}\text{Th}$ radiogenic isotope ratio along with the corresponding measurement uncertainty estimates. All uncertainty estimates were to be reported at the 68% confidence level (1SE, and guidance was provided in an attempt to achieve consistency in derivation). The participating laboratories were also asked to report key parameters of their measurement procedures. Data were evaluated according to four distinct measurement principles: SIMS, laser ablation sector field mass spectrometry (LA-ICP-MS: SFI), laser ablation quadrupole mass spectrometry (LA-ICP-MS: Quad) and “other”. For each of these four measurement principles the standard deviation for proficiency (s_{pt} ; hereafter referred to as “target precision”) was defined as the median value of the uncertainty estimates reported for that specific instrument class. These parameters are reported on Table A.

Table A: List of assigned ages, isotope ratios, their uncertainties (1SE) and corresponding target precision (S_{pt}) values for the six measurands of Kara-18 zircon that are reported.

206Pb/238U Age				
Assigned Age (Ma)	Uncertainty (Ma)	Analytical Technique	Target Precision (S_{pt}, Ma)	Number of Values Reported
2628.38	0.95	SIMS	3.60	4
2628.38	0.95	LA-ICP-MS: SFI	14.2	12
2628.38	0.95	LA-ICP-MS: Quad	7.80	33
2628.38	0.95	OTHER	14.6	1
207Pb/206Pb Age				
Assigned Age (Ma)	Uncertainty (Ma)	Analytical Technique	Target Precision (S_{pt}, Ma)	Number of Values Reported
2632.52	0.56	SIMS	1.45	4
2632.52	0.56	LA-ICP-MS: SFI	5.91	12
2632.52	0.56	LA-ICP-MS: Quad	4.80	33
2632.52	0.56	OTHER	18.4	1
208Pb/232Th Age				
Assigned Age (Ma)		Analytical Technique	Median Uncertainty (1SE, Ma)	Number of Values Reported
Not assigned		SIMS	6.75	4
Not assigned		LA-ICP-MS: SFI	36.2	8
Not assigned		LA-ICP-MS: Quad	19.7	27
206Pb/238U Ratio				
Assigned Ratio	Uncertainty	Analytical Technique	Target Precision (S_{pt})	Number of Values Reported
0.503398	0.000221	SIMS	0.00138	4
0.503398	0.000221	LA-ICP-MS: SFI	0.00226	12
0.503398	0.000221	LA-ICP-MS: Quad	0.00186	33
0.503398	0.000221	OTHER	0.00339	1
207Pb/206Pb Ratio				
Assigned Ratio	Uncertainty	Analytical Technique	Target Precision (S_{pt})	Number of Values Reported
0.177807	0.000060	SIMS	0.000155	4
0.177807	0.000060	LA-ICP-MS: SFI	0.000515	12
0.177807	0.000060	LA-ICP-MS: Quad	0.000550	33
208Pb/232Th Ratio				
Assigned Ratio		Analytical Technique	Median Uncertainty (1SE)	Number of Values Reported
Not assigned		SIMS	0.000375	4
Not assigned		LA-ICP-MS: SFI	0.00225	11
Not assigned		LA-ICP-MS: Quad	0.00112	30

Notes:

Table A is an enhanced version of Table 1 which appears later in this report.

Assigned ages are best estimates. Target Precisions are taken as the median value of reported uncertainties (1SE) for each analytical technique/measurement principle. Due to the lack of an assigned value for the Th-Pb chronometer, no target precision can be defined but median uncertainty values (1SE) are listed.

Codes:

SIMS = Secondary Ion Mass Spectrometry (ion probe)

LA-ICP-MS: SFI = Laser Ablation Inductively Coupled Plasma Mass Spectrometry – Sector Field mass spectrometer

LA-ICP-MS: Quad = Laser Ablation Inductively Coupled Plasma Mass Spectrometry – Quadrupole mass spectrometer

Review of Results

The age results contributed by all 50 reporting laboratories are presented in Table 2, ordered according to analytical technique/measurement principle and identified by a randomised laboratory code to ensure complete anonymity of participating laboratories. This table lists not only the ages and their reported precision estimates but also their corresponding z-scores, explained below, indicative of the given laboratory's performance relative to the TIMS-defined assigned value. Table 2 also presents some of the details of the procedures employed. A variety of reference materials were used, with zircon 91500 being used by over 60% of the reporting laboratories.

For G-Chron Round #2 a new data submission category was provided, allowing the participating laboratories to submit their determined radiogenic $^{206}\text{Pb}/^{238}\text{U}$, $^{207}\text{Pb}/^{206}\text{Pb}$ and $^{208}\text{Pb}/^{232}\text{Th}$ isotope ratios. These values are listed in Table 3. They should be closely linked to the reported ages for these two chronometers through the use of identical radioactive decay constants, but in rare cases the two values do not agree within expectations, suggesting possible errors during data input.

Globally there are few TIMS laboratories that routinely investigate the Th-Pb zircon system. For the current round of G-Chron we were not able to recruit such a laboratory, and as such we have neither target values for the $^{208}\text{Pb}/^{232}\text{Th}$ age nor for the radiogenic $^{208}\text{Pb}/^{232}\text{Th}$ ratio. Nonetheless, this report provides distribution plots (Figures 3 & 6) for the Th-Pb results from the participating laboratories. This will allow programme participants to compare their results for the $^{208}\text{Pb}/^{232}\text{Th}$ chronometer with those submitted by other laboratories from their peer group. The lack of defined target values means that no z-scores can be provided for the Th-Pb system.

Observations relating to the distribution of age results may be made, not only from Table 2, but more easily from Figures 1, 2 and 3. Data for each isotopic system are ordered according to increasing age, shown with the reported 1SE uncertainties as error bars, which are colour coded according to which of the four laboratory methods was used. Additionally, each of these figures shows how submitted results, identified by laboratory code, compare with the assigned TIMS-derived target age. For the $^{206}\text{Pb}/^{238}\text{U}$ age, a number of laboratories submitted results in close agreement with the target 2628.38 Ma age. However, many results diverge significantly. Figure 1 clearly shows a bias toward $^{206}\text{Pb}/^{238}\text{U}$ ages that are too old and no obvious plateau is visible in the distribution plot. For the $^{207}\text{Pb}/^{206}\text{Pb}$ age, the dataset is better centred on the 2632.52 Ma assigned age, though at both ends of the spectrum there are results that diverge by more than 10 Ma from the assigned value. In general, quoted uncertainty estimates are smallest for SIMS, and range from relatively small to quite large for both LA-ICP-MS: SFI and LA-ICP-MS: Quad data sets. Finally, we note that Figure 3 reveals the lack of a clear consensus age value from the contributed data for the Th-Pb geochronometer.

The wide variations in the uncertainty estimates by almost all methods makes for difficulties in assigning appropriate values as target precisions for the assessment of results (see later). Figures 1, 2 and 3 reveal a number of laboratories reporting ages close to the assigned target values yet have large uncertainty assignments. In contrast, some reported ages differ significantly from the target ages, but have rather small uncertainty estimates. The weak correlation between uncertainty estimates and divergence from the target value assigned suggests that a community-wide re-evaluation of data assessment methods could be beneficial. Similar data patterns were described in the G-Chron Round #1 report.

Performance Assessment – Z-scoring

In proficiency testing, z-scoring provides a convenient way for laboratories to assess their performance in relation to a pre-defined fitness-for-purpose criterion. A z-score is a scaled measure of the deviation of the reported measurement result from an assigned value. We calculated z-scores for each of the contributed measurement results as follows:

$$z_i = [x_i - x_{pt}] / s_{pt}$$

where x_i is a reported laboratory result, x_{pt} is the assigned value (based on ID-TIMS data) and s_{pt} is the target precision. The target precision to be applied in age determinations has no historical precedent, unlike some other classes of geochemical analysis. Consequently, for the purposes of the G-Chron programme we have elected to define the target precision as the median of the reported (1SE) values for a particular measurement procedure: SIMS, LA-ICP-MS: SFI, LA-ICP-MS: Quad and “other”. We should emphasize that as PT programmes applied to isotopic age determination is not a well-developed field, with no generally accepted performance criteria, this approach to defining target precisions must be viewed as experimental at this time. The target precision values applicable for this round of G-Chron are listed in Tables A and B. For the analytical technique/measurement principle “other” there was only a single submission, making the s_{pt} value effectively meaningless. In the case of the measurement principle “SIMS” there were only four participating laboratories, so we recommend caution when interpreting the z-scores for this subset of data.

Table B: Listing of target precision (s_{pt}) values and the limits of 'satisfactory' ranges whereby $-2 \leq z \leq 2$, for each isotopic system and each analytical procedure. Due to the lack of an assigned value for the Th-Pb chronometer it was not possible to provide z-scores for the thorium radioactive decay system.

Parameter	Analytical Technique/ Measurement Principle	Target Precision ($z = 1$)	Satisfactory Range ($z = \pm 2$)
		s_{pt}	$\pm 2 s_{pt}$
$^{206}\text{Pb}/^{238}\text{U}$ age	SIMS	3.60 Ma	7.20 Ma
$^{206}\text{Pb}/^{238}\text{U}$ age	LA-ICP-MS: SFI	14.2 Ma	28.4 Ma
$^{206}\text{Pb}/^{238}\text{U}$ age	LA-ICP-MS: Quad	7.80 Ma	15.6 Ma
$^{206}\text{Pb}/^{238}\text{U}$ age	Other	14.6 Ma*	29.2 Ma*
$^{207}\text{Pb}/^{206}\text{Pb}$ age	SIMS	1.45 Ma	2.90 Ma
$^{207}\text{Pb}/^{206}\text{Pb}$ age	LA-ICP-MS: SFI	5.91 Ma	11.82 Ma
$^{207}\text{Pb}/^{206}\text{Pb}$ age	LA-ICP-MS: Quad	4.80 Ma	9.60 Ma
$^{207}\text{Pb}/^{206}\text{Pb}$ age	Other	18.4 Ma*	36.8 Ma*
$^{206}\text{Pb}/^{238}\text{U}$ isotope ratio	SIMS	0.00138	0.00276
$^{206}\text{Pb}/^{238}\text{U}$ isotope ratio	LA-ICP-MS: SFI	0.00226	0.00452
$^{206}\text{Pb}/^{238}\text{U}$ isotope ratio	LA-ICP-MS: Quad	0.00186	0.00372
$^{206}\text{Pb}/^{238}\text{U}$ isotope ratio	Other	0.00339*	0.00678*
$^{207}\text{Pb}/^{206}\text{Pb}$ isotope ratio	SIMS	0.000155	0.000310
$^{207}\text{Pb}/^{206}\text{Pb}$ isotope ratio	LA-ICP-MS: SFI	0.000515	0.001030
$^{207}\text{Pb}/^{206}\text{Pb}$ isotope ratio	LA-ICP-MS: Quad	0.000550	0.001100

*Values to be regarded with extreme caution due to the very limited size of the dataset.

The individual z-scores for the $^{206}\text{Pb}/^{238}\text{U}$ and $^{207}\text{Pb}/^{206}\text{Pb}$ ages reported for Kara-18 are listed in Table 2. Likewise, corresponding values for the reported isotope ratios are listed in Table 3. As is routine in proficiency testing, participating laboratories are invited to assess their performance using the following criteria: z-score results in the range $-2 < z < 2$ are considered to be 'satisfactory', in the sense that no action by the participant is required. 'Satisfactory' ranges are shown graphically in the form of 'error bars' at the right-hand sides of Figures 1, 2, 4 and 5. In particular, Figure 7 allows participating laboratories to readily assess whether their reported age can be considered 'satisfactory' according to the $-2 < z < 2$ criterion and also whether their submitted results are consistent with their own uncertainty estimates (as shown by the error bars for individual laboratories). If the z-score for any result falls outside this range, and especially if it is outside the range $-3 < z < 3$, laboratories are encouraged to examine their procedures and, if necessary, take appropriate action to ensure that their determinations are not subject to one or more sources of unsuspected measurement bias.

There is a consequence of this approach for defining a target precision for each particular isotopic age system and for each particular measurement procedure based on the median of the reported measurement uncertainties: the performance of a given laboratory is assessed in relation to the performance of its methodological peer group. Hence, a given age result obtained by one method that is outside the 'satisfactory' range according to the assigned z-score, implying the presence of significant bias, might in the case of a different measurement procedure well have resulted in a 'satisfactory' z-score. We ask participating laboratories to take note of this possibility.

We are aware that our empirically derived target precisions, and therefore the derived z-scores, provide a somewhat generalized portrait of laboratory performance. We therefore additionally recommend that participants check the difference between their laboratory's reported age and the assigned age. If this difference is greater than twice the reported measurement uncertainty estimated at the 68% confidence level then a review of the methodology for assigning uncertainties would be prudent.

Overall Performance

A summary of the overall performance of individual laboratories for G-Chron Round #2 is provided by a multiple z-score chart shown in Figure 7. In this chart the z-score performance for each result is distinguished by symbols that make it easy to identify whether the measurement results were satisfactory or if they gave z-scores that exceeded the action limits (as shown by either the small or large triangle symbols). This chart is designed to help individual laboratories judge their overall performance within the context of this proficiency test. Note, however, that participants should always review their z-scores in accordance with their own fitness-for-purpose requirements.

Future G-Chron Participation

As the first two rounds of the G-Chron proficiency test provided unique insights into data trends within the geoanalytical community, it is planned that further such rounds of G-Chron will be conducted. Assuming suitable material can be obtained, in conjunction with the ongoing support from expert ID-TIMS laboratories, it is intended that such proficiency tests will be conducted at roughly one to two year intervals. As zircon is the most widely employed phase for U-(Th)-Pb geochronology research, zircon will remain the focus of future rounds. However, if suitably concordant material from other geochronologically important mineral phases can be obtained then such materials may also be employed in the G-Chron testing programme. News concerning upcoming rounds will be made available via both the www.geoanalyst.org and www.qchron.info websites.

Future Actions Planned for the Kara-18 Material

Due to the good yield of zircon from the collected rock starting material, over 420 units of Kara-18 zircon still remain. This material will be made available to the geoanalytical community via www.IAGeo.com, the website of IAGeo Limited, which is the trading arm of the International Association of Geoanalysts. It will be available for distribution once the characterization report for this material has been published in the scientific literature.

It is intended that a discussion of the results from the first two rounds of the G-Chron proficiency test along with data patterns found in upcoming rounds will be submitted for publication at a future date. That paper will also explore possible origins of the differing age results between the various radioactive decay systems. Links to reports and scientific literature resulting from the G-Chron programme will be provided by the www.geoanalyst.org website at an appropriate time.

Acknowledgements

The authors wish to thank the following for various forms of assistance they have given to this programme: the three expert TIMS laboratories for their analytical contributions; Frédéric Couffignal for providing SIMS data; Juliane Herwig for assistance with mineral separation; and Phil Potts for guidance during the early design of the programme. We also express our appreciation to Tim Ivanic and Michael Wingate of the Department of Mines in Perth for providing information about the Kara locality and assistance with the rock export permits. Finally, we want to especially thank Julie and Peter Woodhead of Karara Station for all their friendly support during the three days of sometimes rainy field sampling.

References

- Steiger R.H. and Jäger E. (1977) Subcommittee on geochronology: convention on the use of decay constants in geo- and cosmochronology. *Earth and Planetary Science Letters*, 36, 359-362.
- Wiedenbeck M. and Watkins K.P. (1993) A time scale for granitoid emplacement in the Archean Murchison Province, Western Australia, by single zircon geochronology. *Precambrian Research*, 61, 1-26.
- Wiedenbeck M., Allé P., Corfu F., Griffin W.L., Meier M., Oberli F., von Quadt A., Roddick J.C. and Spiegel W. (1995). Three natural zircon standards for U-Th-Pb, Lu-Hf, trace element and REE analyses. *Geostandards Newsletter*, 19, 1-23.

Previous Report

Webb P., Wiedenbeck M. and Glodny J. (2020) G-Chron 2019 – Round 1 — An International Proficiency Test for U-Pb Geochronology Laboratories — Report on the 2019 Round of G-Chron based on Palaeozoic Zircon Rak-17 (Distribution: September 2019). International Association of Geoanalysts: Keyworth. Unpublished report.

Table 1 - G-Chron 2 Kara-18, Zircon - Assigned ages and corresponding uncertainties (1SE), with target precisions for each isotopic system and each analytical procedure.

206Pb/238U Age (Ma)	Uncertainty (Ma)	Analytical Technique	Target Precision (Ma)	Number of Values Reported
2628.38	0.95	SIMS	3.60	4
2628.38	0.95	LA-ICP-MS: SFI	14.2	12
2628.38	0.95	LA-ICP-MS: Quad	7.80	33
2628.38	0.95	OTHER	14.6	1
207Pb/206Pb Age (Ma)	Uncertainty (Ma)	Analytical Technique	Target Precision (Ma)	Number of Values Reported
2632.52	0.56	SIMS	1.45	4
2632.52	0.56	LA-ICP-MS: SFI	5.91	12
2632.52	0.56	LA-ICP-MS: Quad	4.80	33
2632.52	0.56	OTHER	18.4	1
206Pb/238U Ratio	Uncertainty	Analytical Technique	Target Precision	Number of Values Reported
0.503398	0.000221	SIMS	0.00138	4
0.503398	0.000221	LA-ICP-MS: SFI	0.00227	12
0.503398	0.000221	LA-ICP-MS: Quad	0.00186	33
0.503398	0.000221	OTHER	0.00339	1
207Pb/206Pb Ratio	Uncertainty	Analytical Technique	Target Precision	Number of Values Reported
0.177807	0.00006	SIMS	0.000155	4
0.177807	0.00006	LA-ICP-MS: SFI	0.000515	12
0.177807	0.00006	LA-ICP-MS: Quad	0.000550	33

Note: Assigned ages are best estimates. Target Precisions are derived as the median value of reported uncertainties for each analytical technique category.

Codes: SIMS = Secondary Ion Mass Spectrometry (ion probe)
 LA-ICP-MS: SFI = Laser Ablation Inductively Coupled Plasma Mass Spectrometry - Sector Field mass spectrometer
 LA-ICP-MS: Quad = Laser Ablation Inductively Coupled Plasma Mass Spectrometry - Quadrupole mass spectrometer

Table 2 - G-Chron 2 Contributed data and z-scores for Kara-18, Zircon, ordered according to analytical method and identified by randomised laboratory code. 19/01/2022

Lab Code	Method	206Pb /238U Age (Ma)	206Pb /238U Uncer-tainty (1SE, Ma)	206Pb /238U z-score	207Pb /206Pb Age (Ma)	207Pb /206Pb Uncer-tainty (1SE, Ma)	207Pb /206Pb z-score	208Pb /232Th Age (Ma)	208Pb /232Th Uncer-tainty (1SE, Ma)	208Pb /232Th z-score	Total Number of Measurements	Number of Rejections	Common Pb Correction	ID Spike	RM Name	RM 206Pb /238U Age (Ma)	RM 206Pb /238U Age 1SE (Ma)
B19	SIMS	2622.5	4.7	-1.63	2630.3	1.6	-1.53	2611.1	7.9		36	0	204Pb ancient		Temora2	416.78	0.64
B23	SIMS	2625.8	3.1	-0.72	2625.4	1.3	-4.91	2593.0	10.0		29	4	204Pb ancient		Temora2	416.8	1.6
B51	SIMS	2630.3	4.1	0.53	2633.3	1.9	0.54	2600.2	5.2		38	4	204Pb modern		91500	1062	3.1
B66	SIMS	2628.0	1.3	-0.11	2629.2	1.2	-2.29	2631.2	5.6		36	0	204Pb modern		M257	561.3	0.4
B4	LA-ICP-MS: SFI	2658.69	22.44	2.13	2643.18	7.02	1.80	2682.53	25.63		74	34	none		91500	1064,1	4,4
B7	LA-ICP-MS: SFI	2647.1	2.9	1.32	2627.3	2.6	-0.88				128	4	none		91500	1065	1.3
B10	LA-ICP-MS: SFI	2616.5	3.4	-0.84	2624.7	1.7	-1.32				81	33	none		91500	1065	0.6188
B12	LA-ICP-MS: SFI	2654.0	13.5	1.80	2631.05	4.68	-0.25	2665.3	32.1		50	13	none		91500	1063.805	0.8
B14	LA-ICP-MS: SFI	2622.8	85.8	-0.39	2629.1	42.0	-0.58				240	20	none		91500	1065	10
B38	LA-ICP-MS: SFI	2645.5	14.9	1.21	2627.9	9.1	-0.78	2568.4	64.2		16	0	none		91500	1061	1
B39	LA-ICP-MS: SFI	2614.7	9.0	-0.96	2645.3	2.8	2.16	2603.8	40.4		36	6	none		91500	1062.4	2.0
B45	LA-ICP-MS: SFI	2619.7	18.2	-0.61	2629.7	11.1	-0.48	2545.6	75.3		70	6	other		GJ-1	600.4	2.4
B50	LA-ICP-MS: SFI	2727.7	6.0	6.99	2612.4	4.8	-3.40	2784.0	20.0		40	12	none		91500	1065	2.2
B54	LA-ICP-MS: SFI	2632.8	17.4	0.31	2633.5	17.3	0.17	2663.2	23.2		34	6	none		GJ-1	601.86	0.37
B58	LA-ICP-MS: SFI	2630.3	5.1	0.14	2636.6	0.8	0.69				30	0	none		Other	1830.5	2.4
B72	LA-ICP-MS: SFI	2623.2	27.0	-0.36	2623.7	11.2	-1.49	2568.5	79.9		16	1	none		GJ-1	600.62	2.4
B2	LA-ICP-MS: Quad	2641.4	4.0	1.67	2630.8	2.2	-0.36	2624.9	12.5		20	1	none		91500	1062	0.00035
B13	LA-ICP-MS: Quad	2761.3	121.0	17.04	2628.3	27.9	-0.88	2931.6	71.4		14	8	none		91500	1062.4	34.2
B15	LA-ICP-MS: Quad	2636.4	4.4	1.03	2639.1	1.5	1.37	2535.0	15.5		25	0	none		91500	1064	
B16	LA-ICP-MS: Quad	2650.7	5.6	2.86	2633.2	3.4	0.14	2693.9	21.2		40	5	none		GJ-1	600.7	0.4
B17	LA-ICP-MS: Quad	2611.17	24.6	-2.21	2624.6	10.32	-1.65	2589.43	29.92		6	0	none		91500	1065	
B18	LA-ICP-MS: Quad	2668.1	2.7	5.09	2643.5	1.7	2.29	2693.7	4.9		80	28	none		91500	1062.4	1.0
B22	LA-ICP-MS: Quad	2632.0	5.0	0.46	2622.0	6.0	-2.19	2632.0	8.0		30	5	none		91500	1065	7.6
B24	LA-ICP-MS: Quad	2643.3	6.7	1.91	2657.1	5.0	5.12	2651.0	14.5		28	-30	none		91500	1062.4 Ma	4.1 Ma (2 standar
B25	LA-ICP-MS: Quad	2696.1	8.79632	8.68	2632.61	1.98953	0.02	2741.95	19.6643		30	0	none		91500	1063.51	2.9
B26	LA-ICP-MS: Quad	2598.7	30.4	-3.81	2587.2	10.6	-9.44	2557.7	25.9		50	0	204Pb ancient		Other	523	5
B27	LA-ICP-MS: Quad	2637.58	3.75	1.18	2643.39	3.03	2.26	2659.14	16.23		50	18	none		91500	1063.23	2.54
B28	LA-ICP-MS: Quad	2634.1	2.2	0.73	2639.0	3.1	1.35				90	13	none		91500	1063	0.5
B29	LA-ICP-MS: Quad	2627.3	19.2	-0.14	2695.5	13.3	13.12	2838.0	81.0		60	14	none		91500	1062.1	5.5
B30	LA-ICP-MS: Quad	2638.28	2.92	1.27	2628.81	3.96	-0.77	2639.8	13.6		39	5	none		GJ-1	600.46	1.5
B31	LA-ICP-MS: Quad	2641.6	19.5	1.69	2631.0	32.3	-0.32	2666.8	52.0		35	2	none		91500	1062Ma	±10Ma
B32	LA-ICP-MS: Quad	2648.0	7.0	2.52	2630.3	4.2	-0.46	2696.0	19.0		100	8	none		91500	1065.0	1.3
B36	LA-ICP-MS: Quad	2719.4	23.5	11.67	2769.1	9.6	28.45	2760.0	120.0		20	2	none		91500	1065	5.7
B37	LA-ICP-MS: Quad	2556.38	9.09929	-9.23	2640.22	10.9009	1.60	2538.0	17.0		44	3	none		FC-1	1099	3.1 (2s)

Table 2 - G-Chron 2 Contributed data and z-scores for Kara-18, Zircon, ordered according to analytical method and identified by randomised laboratory code. 19/01/2022

Lab Code	Method	206Pb /238U Age (Ma)	206Pb /238U Uncer-tainty (1SE, Ma)	206Pb /238U z-score	207Pb /206Pb Age (Ma)	207Pb /206Pb Uncer-tainty (1SE, Ma)	207Pb /206Pb z-score	208Pb /232Th Age (Ma)	208Pb /232Th Uncer-tainty (1SE, Ma)	208Pb /232Th z-score	Total Number of Measurements	Number of Rejections	Common Pb Correction	ID Spike	RM Name	RM 206Pb /238U Age (Ma)	RM 206Pb /238U Age 1SE (Ma)
B43	LA-ICP-MS: Quad	2629.0	8.5	0.08	2636.0	7.0	0.73	2753.0	24.5		25	2	none		91500	1062.4	20
B49	LA-ICP-MS: Quad	2568.0	12.0	-7.74	2633.4	4.8	0.18	2534.0	61.0		130	43	none		91500	1065 Ma in the	0.28
B52	LA-ICP-MS: Quad	2618.1	6.61	-1.32	2603.89	5.2	-5.96	2578.56	16.96		35	2	none		Plesovice	337.13	0.48
B53	LA-ICP-MS: Quad	2646.7	18.2	2.35	2635.2	7.0	0.56	2642.3	30.1		38	7	none		91500	1065	2.98
B55	LA-ICP-MS: Quad	2663.2	5.1	4.46	2630.3	1.4	-0.46				22	2	none		91500	1065	3.3
B56	LA-ICP-MS: Quad	2648.3	7.8	2.55	2632.0	3.8	-0.11				24	2	none		Other	2682.4	1
B57	LA-ICP-MS: Quad	2641.4	5.5	1.67	2634.1	5.5	0.33	2650.3	12.6		20	1	none		91500		
B59	LA-ICP-MS: Quad	2628.3	8.2	-0.01	2620.9	6.7	-2.42	2639.9	13.0		49	11	none		91500	1062.4	4.0
B60	LA-ICP-MS: Quad	2630.2	9.3	0.23	2634.3	4.9	0.37	2615.0	45.0		30	14	none		Other	2679	3.3
B61	LA-ICP-MS: Quad	2634.0	5.5	0.72	2628.3	2.8	-0.88				40	4	none		GJ-1	600.5	0.86
B62	LA-ICP-MS: Quad	2684.87	2.2	7.24	2684.64	2.6	10.86				40	7	none		91500	1063.78	0.65
B64	LA-ICP-MS: Quad	2615.1	11.8	-1.70	2629.1	2.5	-0.71	2681.9	5.4		40	0	none		OG1	3438.6	19.1
B67	LA-ICP-MS: Quad	2616.99	3.69	-1.46	2647.89	3.57	3.20	2687.6	22.5		260	200	none		91500	MudTank, Pleso	
B69	LA-ICP-MS: Quad	2636.2	24.5	1.00	2638.4	23.0	1.23	2599.8	67.2		31	7	none				
B71	LA-ICP-MS: Quad	2609.41	8.29	-2.43	2633.53	4.3	0.21				30	9	none		OG1	3465.4	6
B33	OTHER	2632.4	14.6	0.28	2575.3	18.4	-3.11				33	3	none				

Table 3 - G-Chron 2 Contributed isotope ratios for Kara-18, Zircon, ordered according to analytical method and identified by randomised laboratory code. 19/01/2022

Lab Code	Method	206Pb /238U Ratio	206Pb /238U Uncer -tainty (1SE)	206Pb /238U z-score	207Pb /206Pb Ratio	207Pb /206Pb Uncer -tainty (1SE)	207Pb /206Pb z-score	208Pb /232Th Ratio	208Pb /232Th Uncer -tainty (1SE)	208Pb /232Th z-score	Total Number of Measurements	Number of Rejections	Common Pb Correction	ID Spike	RM Name	RM 206Pb /238U Ratio	RM 206Pb /238U Age 1SE (Ma)
B19	SIMS	0.502	0.00126	-1.01	0.17757	0.00017	-1.53	0.13789	0.00044		36	0	204Pb ancient		Temora2	416.78	0.64
B23	SIMS	0.5025	0.0015	-0.65	0.17705	0.00014	-4.88	0.1363	0.0005		29	4	204Pb ancient		Temora2	416.8	1.6
B51	SIMS	0.50368	0.001863	0.20	0.17831	0.00032	3.25	0.13436	0.00027		38	4	204Pb modern		91500	1062	3.1
B66	SIMS	0.50331	0.00031	-0.06	0.17745	0.00013	-2.30	0.13903	0.00031		36	0	204Pb modern		M257	561.3	0.4
B4	LA-ICP-MS: SFI	0.5106	0.0017	3.18	0.17916	0.00027	2.63	0.14243	0.00086		74	34	none		91500	1064,1	4,4
B7	LA-ICP-MS: SFI	0.5077	0.00068	1.90	0.17674	0.00052	-2.07	0.13852	0.00098		128	4	none		91500	1065	1.3
B10	LA-ICP-MS: SFI	0.50068	0.00079	-1.20	0.17734	0.00026	-0.91	0.13853	0.00054		81	33	none		91500	1065	0.6188
B12	LA-ICP-MS: SFI	0.50861	0.0025	2.30	0.17765	0.00025	-0.30	0.14095	0.0015		50	13	none		91500	1063.805	0.8
B14	LA-ICP-MS: SFI	0.50149	0.019986	-0.84	0.17771	0.004462	-0.19	0.2268	0.0038		240	20	none		91500	1065	10
B38	LA-ICP-MS: SFI	0.50741	0.00347	1.77	0.17732	0.00098	-0.95	0.13551	0.00361		16	0	none		91500	1061	1
B39	LA-ICP-MS: SFI	0.5004	0.00211	-1.32	0.17919	0.0003	2.69	0.13762	0.00225		36	6	none		91500	1062.4	2.0
B45	LA-ICP-MS: SFI	0.5014	0.00423	-0.88	0.17751	0.00118	-0.58	0.13423	0.00424		70	6	other		GJ-1	600.4	2.4
B50	LA-ICP-MS: SFI	0.52675	0.00143	10.31	0.17577	0.00051	-3.96	0.14923	0.0012		40	12	none		91500	1065	2.2
B54	LA-ICP-MS: SFI	0.50441	0.00242	0.45	0.17801	0.00054	0.39	0.14088	0.00505		34	6	none		GJ-1	601.86	0.37
B58	LA-ICP-MS: SFI	0.50385	0.0012	0.20	0.17833	9e-005	1.02				30	0	none		Other	1830.5	2.4
B72	LA-ICP-MS: SFI	0.5022	0.006283	-0.53	0.17687	0.001191	-1.82	0.13551	0.004483		16	1	none		GJ-1	600.62	2.4
B2	LA-ICP-MS: Quad	0.50644	0.00094	1.64	0.17752	0.00023	-0.52	0.13868	0.0007		20	1	none		91500	1062	0.00035
B13	LA-ICP-MS: Quad	0.5352	0.0281	17.10	0.1775	0.003	-0.56	0.1563	0.0035		14	8	none		91500	1062.4	34.2
B15	LA-ICP-MS: Quad	0.50529	0.00102	1.02	0.17849	0.00039	1.24	0.13363	0.00087		25	0	none		91500	1064	
B16	LA-ICP-MS: Quad	0.50867	0.00131	2.83	0.17801	0.00023	0.37	0.14213	0.00112		40	5	none		GJ-1	600.7	0.4
B17	LA-ICP-MS: Quad	0.49979	0.00573	-1.94	0.1773	0.00115	-0.92	0.13672	0.00168		6	0	none		91500	1065	
B18	LA-ICP-MS: Quad	0.5125	0.00064	4.89	0.17182	0.0002	-10.89	0.14394	0.00027		80	28	none		91500	1062.4	1.0
B22	LA-ICP-MS: Quad	0.50426	0.00105	0.46	0.176	0.00062	-3.29	0.1391	0.00043		30	5	none		91500	1065	7.6
B24	LA-ICP-MS: Quad	0.50688	0.0013	1.87	0.18046	0.00033	4.82	0.14014	0.00076		28	-30	none		91500	1062.4 Ma	4.1 Ma (2 standar
B25	LA-ICP-MS: Quad	0.519316	0.002073	8.56	0.1779	0.000212	0.17	0.144864	0.001111		30	0	none		91500	1063.51	2.9
B26	LA-ICP-MS: Quad	0.49838	0.00706	-2.70	0.17359	0.00111	-7.67	0.13517	0.00148		50	0	204Pb ancient		Other	523	5
B27	LA-ICP-MS: Quad	0.50555	0.000876	1.16	0.178066	0.000356	0.47	0.140694	0.000915		50	18	none		91500	1063.23	2.54
B28	LA-ICP-MS: Quad	0.48542	0.00513	-9.67	0.17853	0.00251	1.31	0.13714	0.00357		90	13	none		91500	1063	0.5
B29	LA-ICP-MS: Quad	0.50385	0.004436	0.24	0.18547	0.001562	13.93	0.1513	0.0047		60	14	none		91500	1062.1	5.5
B30	LA-ICP-MS: Quad	0.505856	0.000422	1.32	0.177559	0.000259	-0.45	0.139702	0.000581		39	5	none		GJ-1	600.46	1.5
B31	LA-ICP-MS: Quad	0.5105	0.0047	3.82	0.1775	0.0034	-0.56	0.0802	0.0035		35	2	none		91500	1062Ma	Â±10Ma
B32	LA-ICP-MS: Quad	0.5084	0.00165	2.69	0.17823	0.00044	0.77	0.1427	0.0022		100	8	none		91500	1065.0	1.3
B36	LA-ICP-MS: Quad	0.414	0.007	-48.06	0.201	0.0033	42.17	0.148	0.008		20	2	none		91500	1065	5.7
B37	LA-ICP-MS: Quad	0.4867	0.0021	-8.98	0.178633	0.001177	1.50	0.13387	0.00093		44	3	none		FC-1	1099	3.1 (2s)

Table 3 - G-Chron 2 Contributed isotope ratios for Kara-18, Zircon, ordered according to analytical method and identified by randomised laboratory code. 19/01/2022

Lab Code	Method	206Pb /238U Ratio	206Pb /238U Uncer-tainty (1SE)	206Pb /238U Ratio z-score	207Pb /206Pb Ratio	207Pb /206Pb Uncer-tainty (1SE)	207Pb /206Pb Ratio z-score	208Pb /232Th Ratio	208Pb /232Th Uncer-tainty (1SE)	208Pb /232Th Ratio z-score	Total Number of Measurements	Number of Rejections	Common Pb Correction	ID Spike	RM Name	RM 206Pb /238U Ratio	RM 206Pb /238U Age 1SE (Ma)
B43	LA-ICP-MS: Quad	0.37451	0.16157	-69.29	0.13773	0.05114	-72.87	0.11066	0.04755		25	2	none		91500	1062.4	20
B49	LA-ICP-MS: Quad	0.4896	0.0028	-7.42	0.17821	0.00052	0.73	0.1335	0.0035		130	43	none		91500	1065 Ma in the	0.28
B52	LA-ICP-MS: Quad	0.50117	0.00153	-1.20	0.1749	0.00055	-5.29	0.13612	0.00096		35	2	none		Plesovice	337.13	0.48
B53	LA-ICP-MS: Quad	0.5075	0.0039	2.21	0.1775	0.0014	-0.56	0.1399	0.0022		38	7	none		91500	1065	2.98
B55	LA-ICP-MS: Quad	0.5116	0.00539	4.41	0.17765	0.00015	-0.29	0.13559	0.0006		22	2	none		91500	1065	3.3
B56	LA-ICP-MS: Quad	0.50839	0.00186	2.68	0.17841	0.0008	1.10				24	2	none		Other	2682.4	1
B57	LA-ICP-MS: Quad	0.50634	0.00128	1.58	0.17796	0.0006	0.28	0.14009	0.00071		20	1	none		91500		
B59	LA-ICP-MS: Quad	0.50439	0.00181	0.53	0.17647	0.00047	-2.43	0.13944	0.00075		49	11	none		91500	1062.4	4.0
B60	LA-ICP-MS: Quad	0.5039	0.0022	0.27	0.17816	0.00053	0.64	0.1382	0.0024		30	14	none		Other	2679	3.3
B61	LA-ICP-MS: Quad	0.50473	0.00129	0.72	0.17731	0.00029	-0.90				40	4	none		GJ-1	600.5	0.86
B62	LA-ICP-MS: Quad	0.516634	0.000523	7.12	0.183578	0.000292	10.49				40	7	none		91500	1063.78	0.65
B64	LA-ICP-MS: Quad	0.177901	0.000271	-175.00	0.500396	0.005365	586.53	0.141922	0.000306		40	0	none		OG1	3438.6	19.1
B67	LA-ICP-MS: Quad	0.4959	0.031	-4.03	0.177	0.0008	-1.47	0.1422	0.0016		260	200	none		91500	MudTank, Pleso	
B69	LA-ICP-MS: Quad	0.50522	0.00572	0.98	0.17842	0.00249	1.11	0.13727	0.00378		31	7	none				
B71	LA-ICP-MS: Quad	0.499109	0.000995	-2.31	0.177953	0.000245	0.27	0.142454	0.00059		30	9	none		OG1	3465.4	6
B33	OTHER	0.50444	0.00339	0.31							33	3	none				

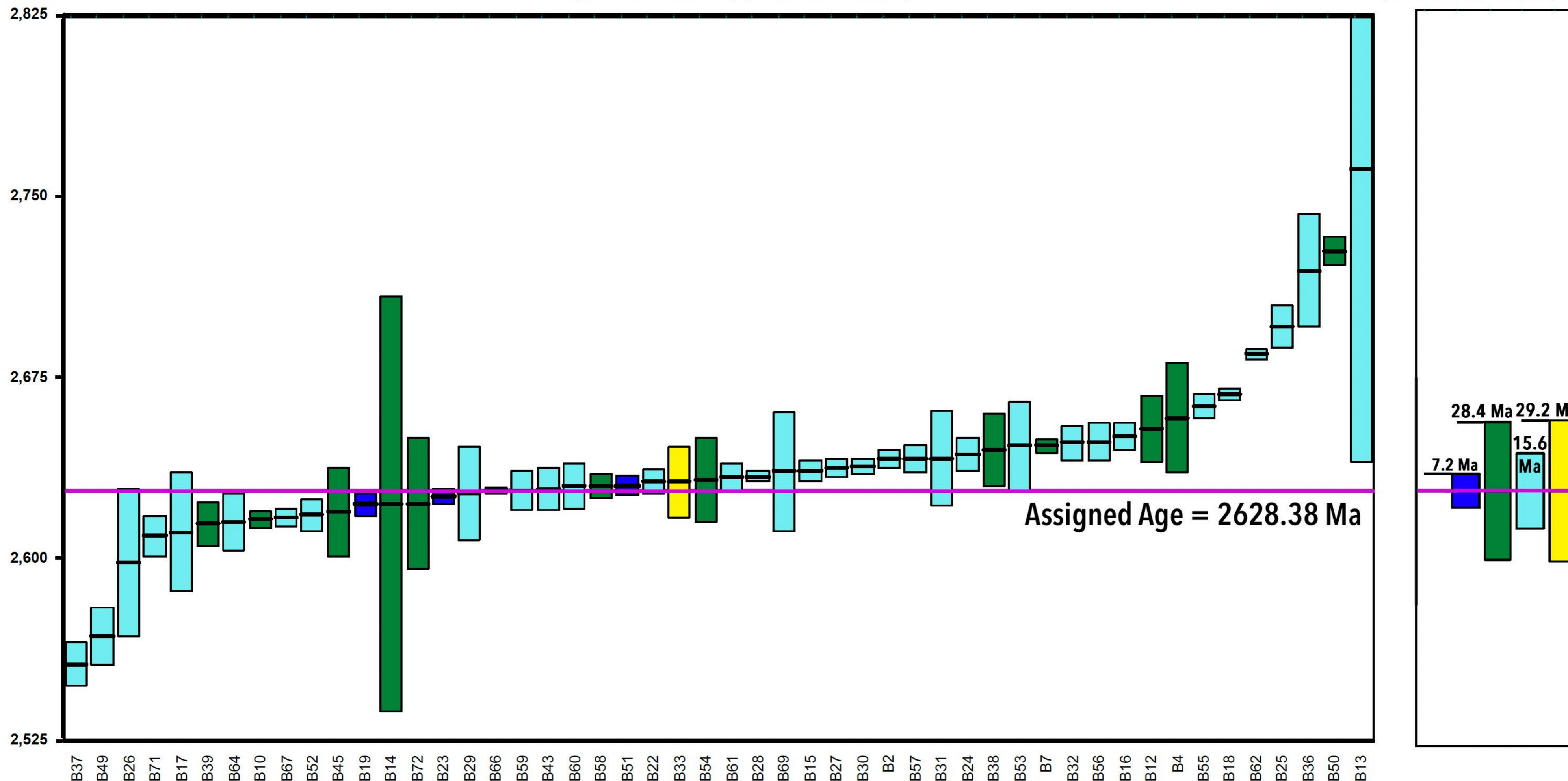
Figure 1: - Ordered distribution of contributed $^{206}\text{Pb}/^{238}\text{U}$ ages with 1SE uncertainties shown as \pm bars for G-Chron 2 in relation to the assigned age, and corresponding satisfactory ranges ($z = \pm 2$) for Kara-18, Zircon

$^{206}\text{Pb}/^{238}\text{U}$

Age (Ma)

a) Results Submitted (ages and uncertainties)

b) Satisfactory Ranges ($z = \pm 2$)



Data plotted in a) according to method, as shown by colour, with reported uncertainties (1SE) shown as error bars.

Satisfactory ranges ($z = \pm 2$) represented in b) for each method.

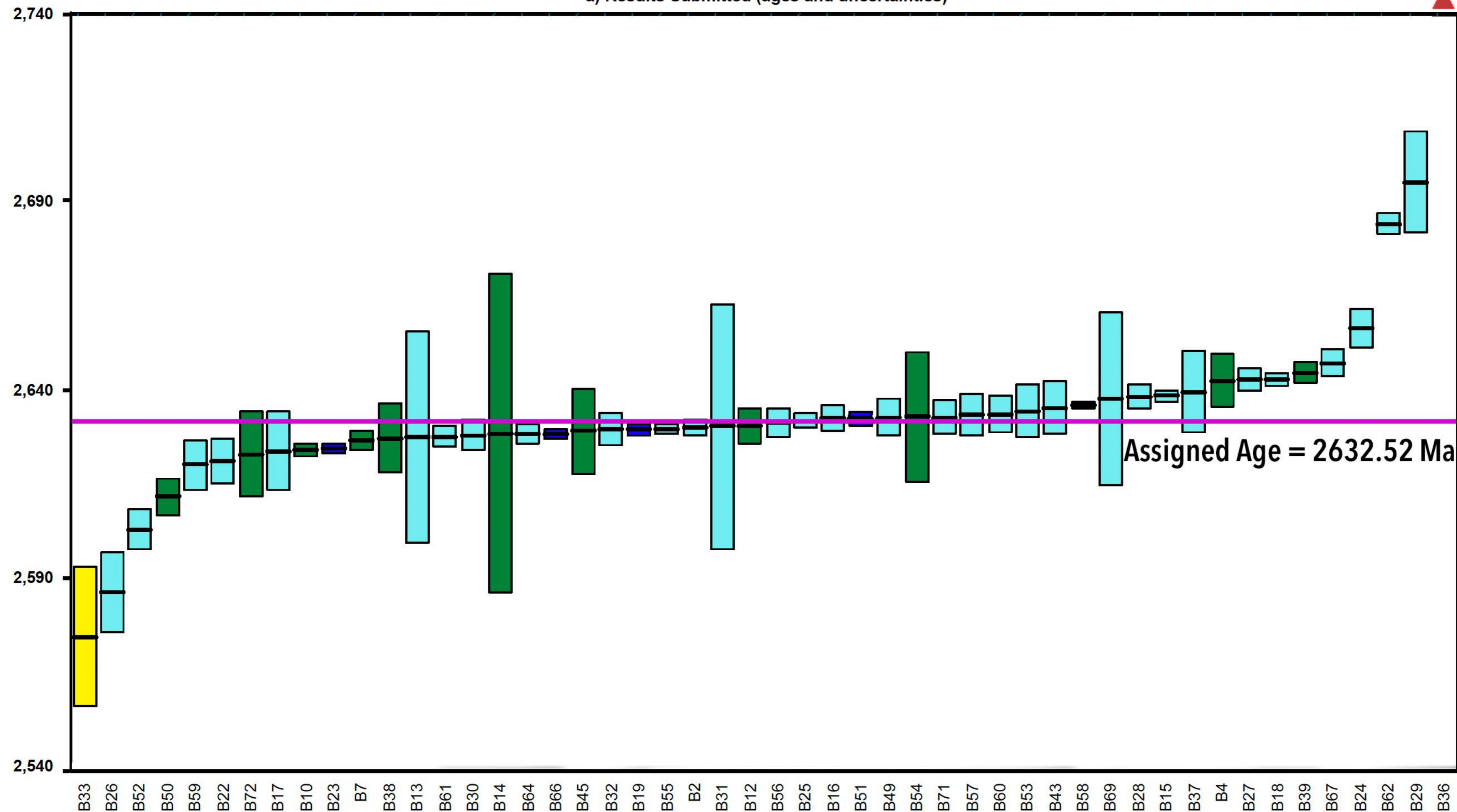
Target Precision ($z = 1$) values (Ma) specified, with colour code defined for each analytical method.

KEY:	Method	Target Precision (Ma)
	SIMS	3.6
	LA-ICP-MS: SFI	14.2
	LA-ICP-MS: Quad	7.8
	Other	14.6

Figure 2: - Ordered distribution of contributed $^{207}\text{Pb}/^{206}\text{Pb}$ ages with 1SE uncertainties shown as \pm bars for G-Chron 2 in relation to the assigned age, and corresponding satisfactory ranges ($z = \pm 2$) for Kara-18, Zircon

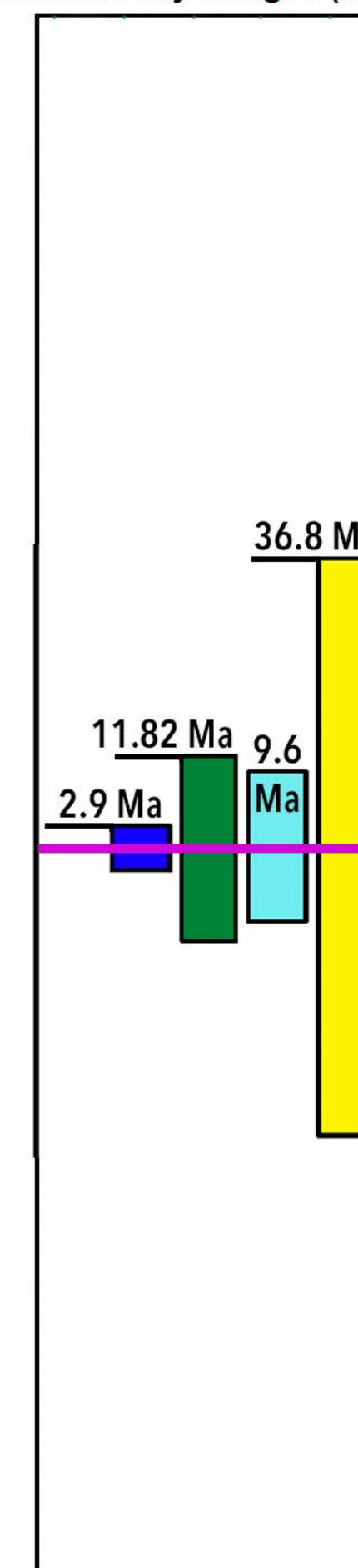
**$^{207}\text{Pb}/^{206}\text{Pb}$
Age (Ma)**

a) Results Submitted (ages and uncertainties)



Off scale

b) Satisfactory Ranges ($z = \pm 2$)



Data plotted in a) according to method, as shown by colour, with reported uncertainties (1SE) shown as error bars.

Satisfactory ranges ($z = \pm 2$) represented in b) for each method.

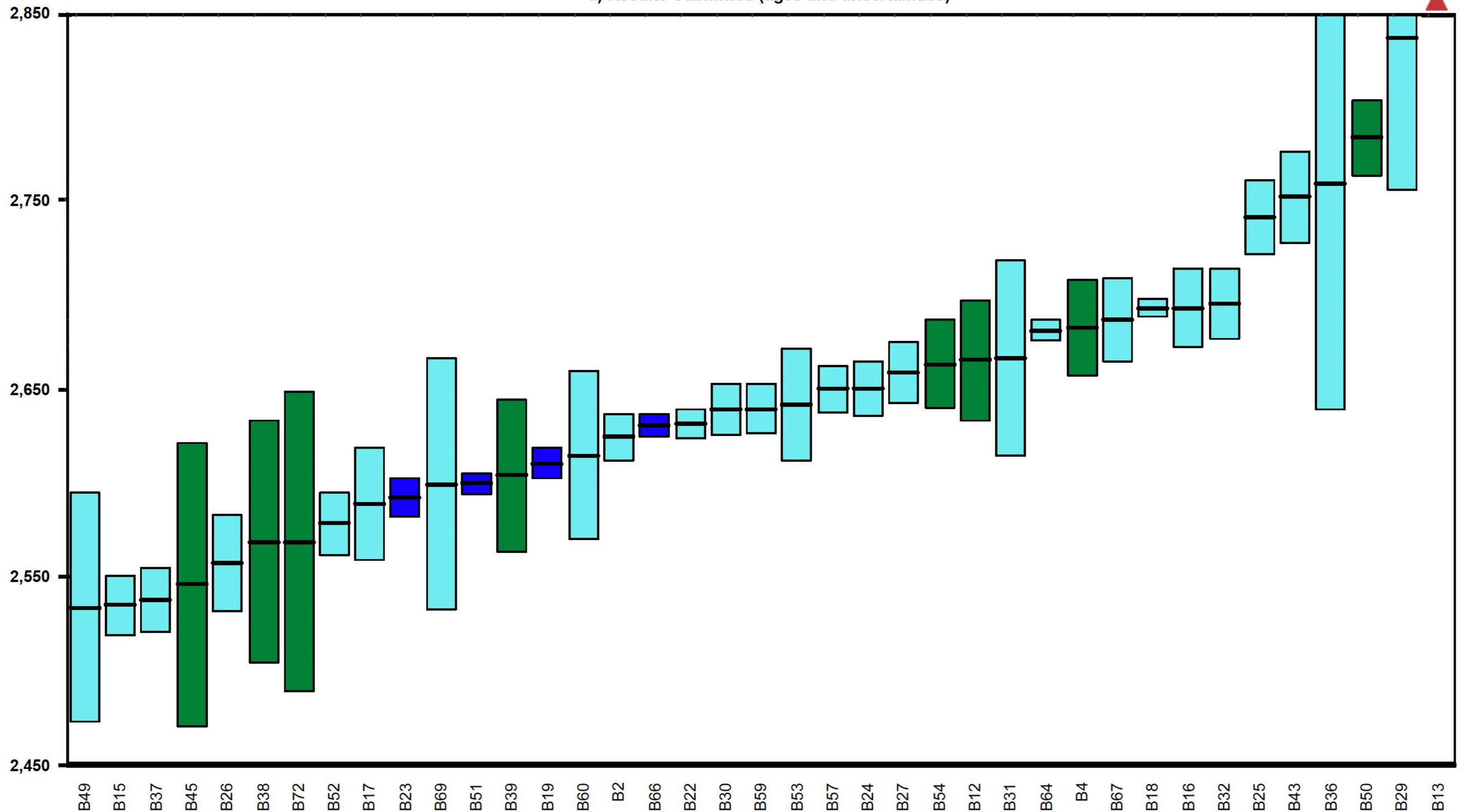
Target Precision ($z = 1$) values (Ma) specified, with colour code defined for each analytical method.

KEY:	Method	Target Precision (Ma)
	SIMS	1.45
	LA-ICP-MS: SFI	5.91
	LA-ICP-MS: Quad	4.80
	Other	18.4

Figure 3: - Ordered distribution of contributed 208Pb/232Th ages with 1SE uncertainties shown as ± bars for G-Chron 2 for Kara-18, Zircon

**208Pb/232Th
Age (Ma)**

a) Results Submitted (ages and uncertainties)

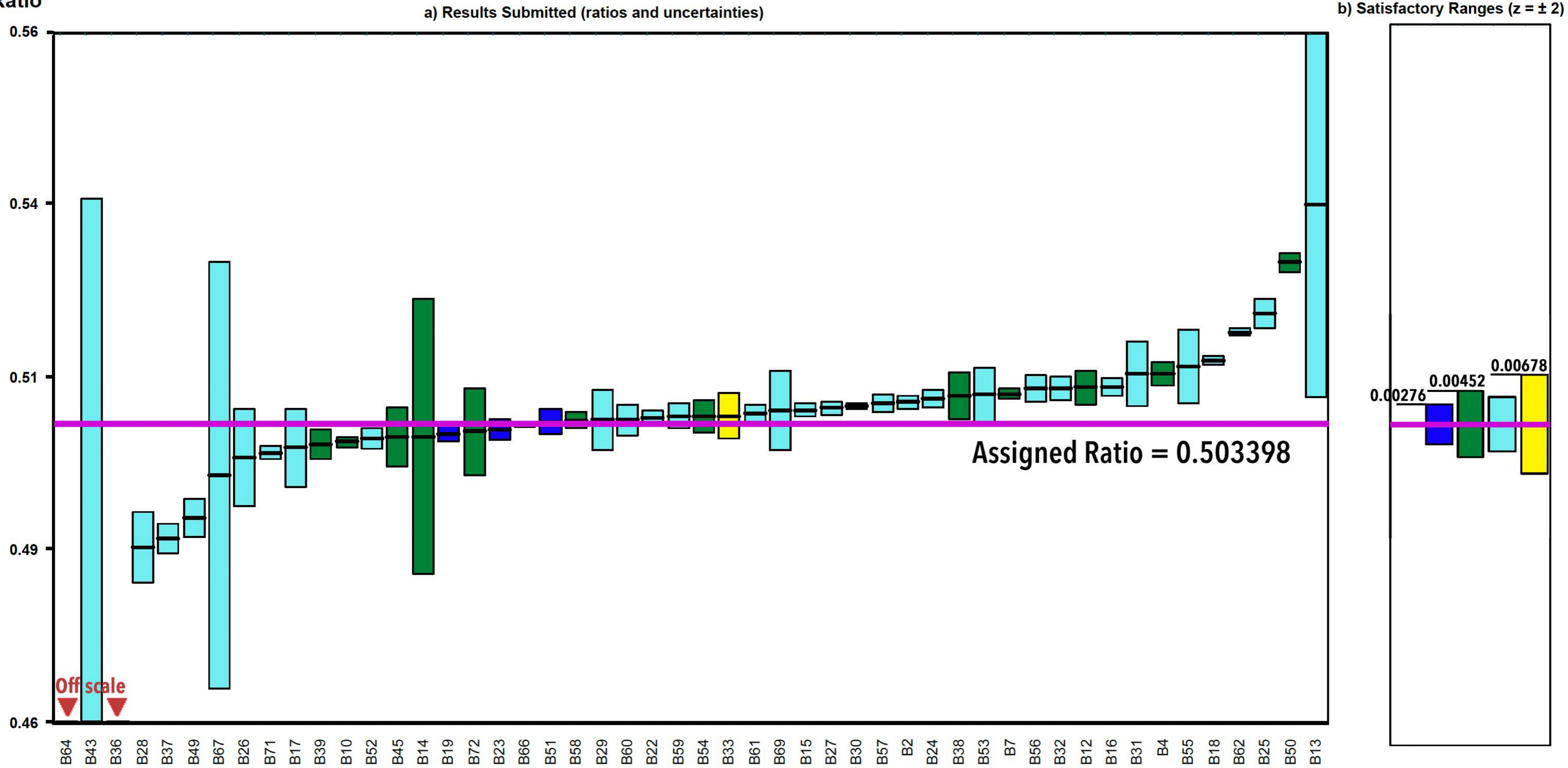


Data plotted in a) according to method, as shown by colour, with reported uncertainties (1SE) shown as error bars.

KEY: SIMS █
 LA-ICP-MS: SFI █
 LA-ICP-MS: Quad █

Figure 4: - Ordered distribution of contributed $^{206}\text{Pb}/^{238}\text{U}$ ratio with 1SE uncertainties shown as \pm bars for G-Chron 2 in relation to the assigned ratio, and corresponding satisfactory ranges ($z = \pm 2$) for Kara-18, Zircon

**$^{206}\text{Pb}/^{238}\text{U}$
Ratio**

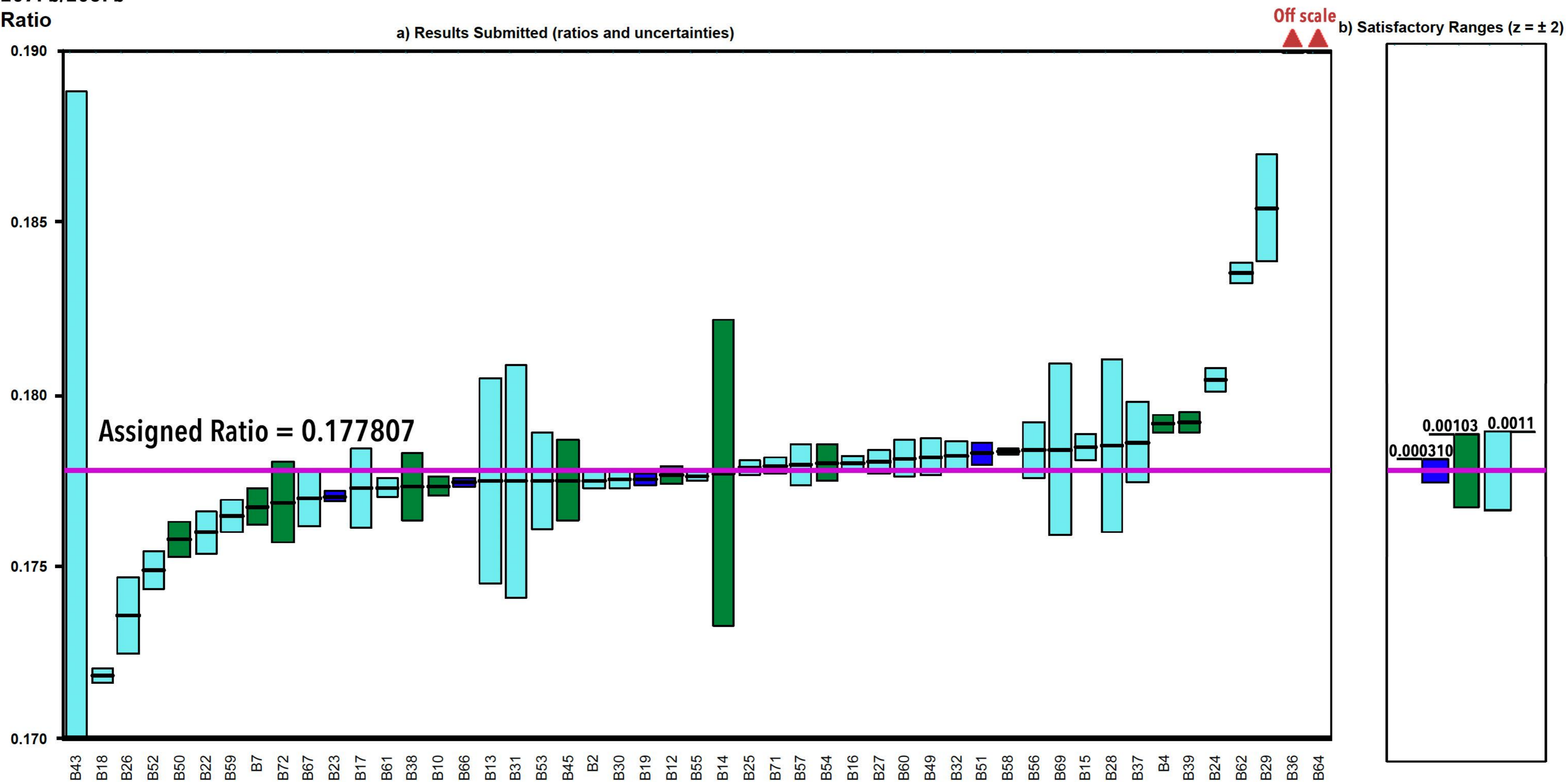


Data plotted in a) according to method, as shown by colour, with reported uncertainties (1SE) shown as error bars. Satisfactory ranges ($z = \pm 2$) represented in b) for each method. Target Precision ($z = 1$) values specified below, with colour code defined for each analytical method.

KEY: SIMS	0.00138
LA-ICP-MS: SFI	0.00226
LA-ICP-MS: Quad	0.00186
Other	0.00339

Figure 5: - Ordered distribution of contributed $^{207}\text{Pb}/^{206}\text{Pb}$ ratio with 1SE uncertainties shown as \pm bars for G-Chron 2 in relation to the assigned ratio, and corresponding satisfactory ranges ($z = \pm 2$) for Kara-18, Zircon

**$^{207}\text{Pb}/^{206}\text{Pb}$
Ratio**



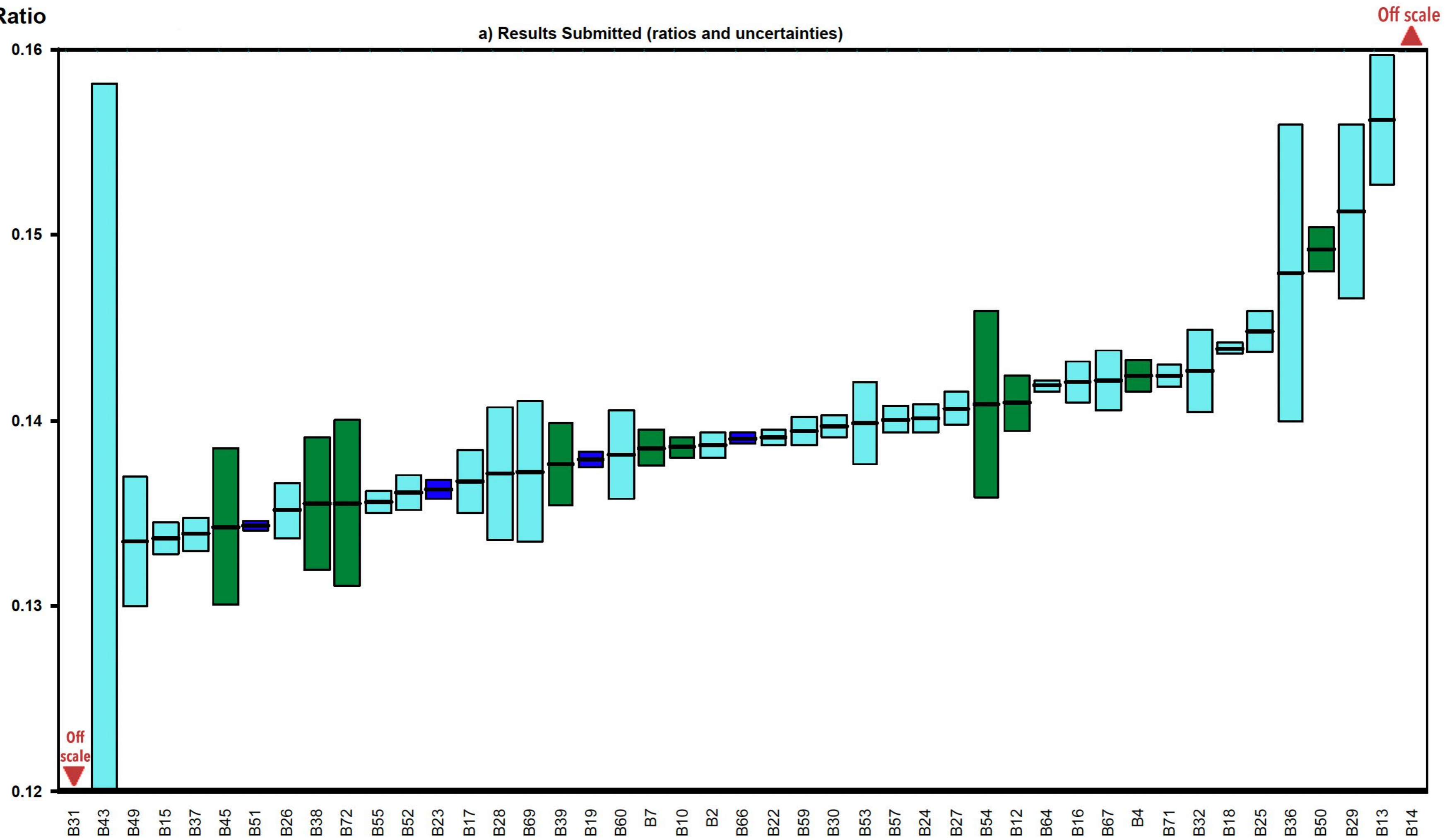
Data plotted in a) according to method, as shown by colour, with reported uncertainties (1SE) shown as error bars. Satisfactory ranges ($z = \pm 2$) represented in b) for each method. Target Precision ($z = 1$) values specified below, with colour code defined for each analytical method.

KEY:	SIMS	0.000155
	LA-ICP-MS: SFI	0.000515
	LA-ICP-MS: Quad	0.000550

Figure 6: - Ordered distribution of contributed $^{208}\text{Pb}/^{232}\text{Th}$ ratio with 1SE uncertainties shown as \pm bars for G-Chron 2 for Kara-18, Zircon

**$^{208}\text{Pb}/^{232}\text{Th}$
Ratio**

a) Results Submitted (ratios and uncertainties)



Data plotted in a) according to method, as shown by colour, with reported uncertainties (1SE) shown as error bars.

KEY: SIMS
 LA-ICP-MS: SFI
 LA-ICP-MS: Quad

Figure 7: G-Chron 2 - Kara-18, Zircon. Multiple z-score charts for laboratories participating in the G-Chron 2 round. Symbols indicate how a reported measurement complies in relation to the criteria keyed below. (see key).

