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**Pre-orogenic upper crustal softening by lower greenschist-facies metamorphic reactions in granites of the central Pyrenees**

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**Pre-orogenic upper crustal softening by lower greenschist-facies metamorphic reactions  
in granites of the central Pyrenees**

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Short title: Pre-kinematic metamorphism in Pyrenees

## ABSTRACT

Pre-kinematic greenschist-facies metamorphism is often observed in granites and basement units of mountains belts, but rarely dated and accounted for in orogenic cycle reconstructions. Studying pre-kinematic alteration is challenging because of its usual obliteration by subsequent syn-kinematic metamorphism often occurring at conditions typical of the brittle-ductile transition. It is however to be expected that pre-kinematic alteration has major implications for the rheology of the upper crust. In the 305 Ma-old Variscan basement of the Bielsa massif (located in the Axial Zone of the Pyrenees), successive fluid-rock interaction events are recorded in granites at temperatures below 350°C. Combined microstructural and petrographic analysis, low-temperature thermobarometry and *in situ* U-Th/Pb dating of anatase, titanite and monazite show extensive pre-orogenic (pre-Alpine) and pre-kinematic alteration related to feldspar sericitization and chloritization of biotite and amphibole at temperatures of 270-350°C at 230-300 Ma. This event is followed by a second fluid-rock interaction stage marked by new crystallisation of phyllosilicates at temperatures of 200-280°C and associated with the formation of mylonitic shear zones and fractures parallel to the shear planes. U-Pb anatase and monazite ages as well as the microtextural relationships of accessory minerals suggest an age for this event at 40-70 Ma, consistent with independent regional geology constraints. The Variscan basement was therefore softened at late- to post Variscan time, at least 150-200 Ma before the main Alpine shortening while Alpine-age compression lead to the formation of a dense net of mylonites. The associated deformation, both distributed at the scale of the Bielsa massif and localized at decametric scale in mylonitic corridors, precedes the strain localization along the major thrusts of the Axial zone. The Bielsa massif is a good example where, inherited,

pre-orogenic upper crustal softening controls the deformation patterns in granitic basement units through low-grade metamorphic reactions.

Key words: U-Th/Pb anatase-titanite-monazite dating, mylonites, chlorite-white mica thermobarometry, Bielsa, Axial zone

## 1. INTRODUCTION

Granites deformed at the brittle-ductile transition show mineral assemblages characteristic of low-grade metamorphism. Greenschist-facies metamorphic reactions often result in the growth of phyllosilicates (e.g. white mica, chlorite) whose presence strongly affect the rheological behaviour of the upper crust through softening, strain localization and fluid migration (Tullis, Yund, & Farver, 1996; Ingles, Lamouroux, Soula, Guerrero, & Debat, 1999; Jackson, Austrheim, McKenzie, & Priestley, 2004; Wintsch, Christoffersen, & Kronenberg, 2005; Goncalves, Oliot, Marquer, & Connolly, 2012). The breakdown of 80 % of feldspar into white mica, for example, reduces the depth of the brittle-ductile transition by two thirds (Gueydan, Leroy, Jolivet, & Agard, 2003). Reactions forming low-grade mineral assemblages responsible for crustal softening are generally observed to be syn-kinematic, occurring during the major deformation phases of an orogenic cycle (Wayne & McCaig, et al., 1998; Gueydan et al., 2003; Mansard, Raimbourg, Augier, Précigout, & Le Breton, 2018). Static or quasi-static hydrothermal alteration is also observed in granites and has been widely documented, especially in large igneous provinces (e.g. Parneix, Beaufort, Dudoignon, & Meunier, 1985; Cathelineau et al., 1986; Yuguchi, Sasao, Ishibashi, & Nishiyama, 2015). However static alteration is rarely characterised, and hardly ever dated and placed in a regional orogenic context. Indeed, low-grade metamorphic reactions often leave tenuous fingerprints only hinted at by equivocal

microtextural relationships, especially in granites (e.g. Airaghi et al., 2017b), which are generally considered poorly reactive rocks at temperatures below 400°C.

At a microscopic scale, pre-kinematic and syn-kinematic transformations are difficult to distinguish, particularly so if the rocks have been deformed through several orogenic cycles. The timing and conditions of pre-kinematic metamorphic reactions and their effects on (i) the syn-kinematic transformation and (ii) the rheological response of the upper crust to successive compressive phases remain therefore poorly constrained. This study addresses these issues by focussing on the Bielsa massif, a Variscan granite located in the Axial Zone of the central Pyrenees (Figure 1a). This massif is an excellent natural laboratory to study how granitic rocks record distinct low-grade metamorphic events. The massif is part of the central Pyrenean belt, which experienced at least two well-known deformation phases (Late Variscan and Alpine/Pyrenean, Cochelin et al. 2017), which are difficult to distinguish in the Axial zone (Cochelin et al, 2017). The Bielsa massif is located in the most external basement domain of the Pyrenees (implying it experienced the lowest peak metamorphic temperatures with respect to Alpine tectonics), south of the zones of large-scale shear bands that have affected other granitic basement units of Pyrenees (e.g. Maladeta, Néouvielle; Wayne & McCaig, 1988). In addition, structural and microstructural studies show significant distributed shortening at the scale of the massif (Román-Berdiel et al., 2004; [Bellahsen et al., 2019](#)), raising questions about the link between low-grade metamorphism and strain accommodation mechanisms. [Early feldspar destabilisation has been proposed to have a major control on subsequent mechanical softening in Bielsa \(Bellahsen et al., 2019\), but the conditions and the age of such reaction still remains unconstrained.](#)

In this contribution we [estimate](#) the conditions of crystallization of both pre-kinematic and syn-kinematic greenschist-facies mineral assemblages in the Bielsa granite and its Triassic sedimentary cover. Microstructural and petrographic analyses were combined with low-

temperature thermobarometry and *in situ* U-Th/Pb dating of zircon, titanite and monazite. Attempt to date anatase (polymorph of rutile) by the U/Pb method were also undertaken. The implications for the timing of crustal softening relative to the major shortening phases are discussed with respect to their associated mineral assemblages. Results suggest that pre-kinematic (pre-Alpine) alteration controls the deformation pattern and strain localisation in the Bielsa granite during Alpine shortening.

## 2. THE BIELSA MASSIF IN THE AXIAL ZONE (CENTRAL PYRENEES)

The Axial zone (central Pyrenees) is part of a S-verging thrust system made of imbricated thrust units stacked during the Late Cretaceous-Early Miocene collision of the Iberian and European plates (Figure 1a). The plutons of the Axial zone (i.e. Bielsa, Neuville, Maladetta massifs etc., Figure 1a) were emplaced into Paleozoic sediments during Late-Variscan (320-300 Ma, e.g. Paquette, Gleizes, Leblanc, & Bouchez, 1997; Vacherat et al., 2017). These plutons and their Paleozoic sedimentary cover constitute the basement to the Permian and Mesozoic sedimentary units (Fig. 1a). Several tectono-metamorphic stages are documented in the metasedimentary units Axial zone but are difficult to distinguish within the basement. Recent studies have proposed that the majority of the deformation in the Axial zone is of Variscan age (Cochelin et al., 2017). Cretaceous hydrothermal events have been identified in the eastern Axial zone (Fallourd et al., 2014; Boutin et al., 2015) and related to extensive tectonics centered on the SE Bay of Biscay. Basement thrusts in the central-western Pyrenees (named Gavarnie and Guarga thrusts) were (re)activated during the Eocene to Miocene (20-30 and 32-36 Ma respectively, Jolivet et al., 2007; Elmola et al., 2018 and references therein). In the hanging wall of the Gavarnie thrust, an older deformation event (*c.* 48 Ma) is recognised in the massifs of Néouvielle and Eaux Chaudes. It has been associated with the activation of mylonitic shear bands (e.g. Wayne & McCaig, 1998).

This study focusses on the Bielsa massif, mainly constituted by a pluton emplaced at *c.* 305 Ma (Vacherat et al., 2017), in the S-verging thrust system structurally located between the Gavarnie and Guarga thrusts (Figure 1b). Close to Lake Urdiceto (Figure 1c-d), granitic to granodioritic rocks (Román-Berdiel et al., 2004) are unconformably overlain by Triassic continental red sandstones and pelites. The basement and its sedimentary cover were deformed (folded) during the Alpine compressional phase (Figure 1d, Casas et al., 2003; Román-Berdiel et al., 2004, Bellashen et al., 2019) with a wavelength of  $\sim 1$  km. Several sub-vertical S- or N-dipping normal or reverse steep faults bound the antiforms and synforms (Figure 1d). In the core of the synforms, Triassic sediments crop out. They exhibit a sub-vertical to N-dipping cleavage (e.g. Figure 2b and 3c), with north side up sense of shear kinematic indicators above the sediment-cover interface (Bellashen et al., 2019). The granitic basement is heterogeneously deformed. At the decametric scale, undeformed and weakly deformed granitic rocks alternate with zones of distributed ductile deformation, zones of fracturing and faulting and mylonites (Figures 1c-d and 2a-f). A pervasive N-dipping schistosity is widespread in the basement (Figure 2a-c and e). Mylonitic corridors, with 1-2 m wide, are observed within the basement and at its boundary with the Triassic sedimentary cover (Figure 2a-c). Mylonitic corridors alternate with less deformed rocks with a wave length of  $\sim 100$  m (Figure 1c) and they are characterized by pervasive schistosity (S) and steep, N-dipping ( $45-70^\circ$ ) and S-dipping ( $55-70^\circ$ ) shear planes (C) associated either with a north or with a south-verging movement (Figure 2a-e). In some shear zone, the dips of mylonitic planes varies from S-dipping to N-dipping, with an apparent sense of shear from top-to-north to top-to-south (Figure 2b-d). Some of the shear bands at the boundary between the Triassic sediments and the late Variscan granite (regionally trending N110, Figure 1c) contain deformed fragments of the Triassic red sandstone (Román-Berdiel et al., 2004; Figure 2b), indicating that they are post-Triassic. The high density of mylonitic corridors and the pervasive schistosity development result in a distributed deformation pattern

(as observed in other crystalline units as the Aar massif, Wehrens et al., 2017). The granitic/granodioritic basement (regardless of the intensity of the strain) is pervasively hydrated and the original magmatic mineral assemblage is partly to totally replaced by greenschist-facies minerals. The steep topography of the massif allows one to infer that the latter replacement affects the pluton at least over a topographic vertical profile of 2 km from the lowest outcrop of the massif (yellow stars in Figures 1b).

At the boundary between the Triassic sediments and the granite/granodiorite, sub-horizontal quartz and chlorite-bearing veins which are 1-5 cm-wide are observed (yellow square in Fig. 3b). Fifty meters from the contact, Triassic sediments show two generations of chlorite- and quartz-bearing veins: (1) sub-horizontal veins parallel to the ones observed at the contact between the basement and the sedimentary rocks produced by vertical extension, locally folded and associated with a crenulation cleavage (N184S) and (2) sub-vertical veins (Figure 3c).

### 3. SAMPLE DESCRIPTION AND CHRONOLOGY OF MINERAL ASSEMBLAGES

Twenty-seven samples were collected along two transects east and west of Lake Urdiceto, from the undeformed granite (e.g. ZA16-84 and B11-16, Figure 4a, b) up to the zone of intense mylonitisation (e.g. ZA16-96, ZA16-98; Figures 1c, 4g). One sample (ZAL18-11) was collected at the contact between the Triassic sandstones and a basement-hosted vein (Figures 3b). Two samples (ZA16-12 and ZA16-13) were collected in the Triassic sediments (Figures 3c).

#### 3.1 Samples from the basement

In the basement unit, we distinguished the following rock fabrics: *Undeformed* samples (e.g. ZA16-84, Figure 4a), where the magmatic, euhedral shape of grains is still preserved. *Weakly deformed* rocks (e.g. Figure 2f and 4c) exhibiting a weak yet pervasive schistosity (at an outcrop scale: S in Figure 2a). In some of those samples the schistosity is associated to mm-scale

fractures (e.g. ZA16-82, ZA16-78, ZA16-128, Figure 4e-f and h) that are parallel to the subvertical shear planes observed at an outcrop scale in mylonites (C in Figure 2a). *Mylonites* showing S and C planes (e.g. ZA16-133, Figure 4g), where the C planes are as pervasive as S. In the samples defined as mylonite, both brittle and ductile deformation features are identified, with the brittle ones underlined by fractures parallel to the shear planes C (Figure 4g).

All samples, regardless of the degree of the strain, exhibit extensive alteration of the magmatic mineral assemblage originally defined by quartz, K-feldspar and plagioclase, biotite  $\pm$  amphibole, apatite, zircon (all in textural equilibrium, Figures 4a-b) and ilmenite preserved as inclusions in the less altered amphibole and biotite grains (Figure 5a-b). The alteration is comprised by the breakdown of plagioclase and K-feldspar into white mica (10-30  $\mu\text{m}$  in size) + albite + calcite  $\pm$  rare epidote (Figure 4a, c, e-f). Biotite and amphibole break down to chlorite flakes (ChlA, abbreviations are from Whitney & Evans, 2010)  $\pm$  white mica (20-100  $\mu\text{m}$  in size)  $\pm$  prehnite (Figure 4a) and a Ti-bearing phase (anatase or titanite or both, Figure 4b, d, f and g). In the paragraph below, mineral assemblages are described in relation to their microstructural evolution from the undeformed granites and granodiorites to mylonites.

In the undeformed samples, relicts of feldspar, biotite and amphibole are still visible and their euhedral magmatic grain shapes are preserved (Figure 4a). Chlorite flakes (ChlA) grow at the grain boundaries of parent minerals and along biotite cleavages, and they are associated with a Ti-bearing phase (see below)  $\pm$  prehnite  $\pm$  K-feldspar (Figure 4a-b). Ilmenite grains are preserved in unaltered biotite and amphibole domains (Figure 5a). Quartz grains contain sparse, micrometric fluid inclusions and are cross-cut by microcracks. Allanite is locally observed in textural equilibrium with the magmatic minerals. Euhedral magmatic zircon grains are found within relicts of feldspar or at the boundaries between feldspar and amphibole. Cathodoluminescence imaging of zircon in samples ZA16-84 and ZA16-119 typically reveals primary oscillatory growth zoning without internal complexity. However, some zircon grains,



especially in sample ZA16-119, show metamictization with porous domains and lobate rims 5-20  $\mu\text{m}$  thick, and very low cathodoluminescence emission (Figure 5d). In the weakly deformed samples, feldspar is pervasively sericitized (up to 80-90%). Original biotite grains are chloritized between 70-90% (Figure 4c). Chlorite flakes (ChlA) and secondary reaction phases (quartz, Ti-phase  $\pm$  white mica) are oriented parallel to the main schistosity and tightly folded to form kinks (Figure 4d). Quartz grains partly preserve their magmatic texture, but are fractured, with fractures subparallel to the kink axes. Grains are cross-cut by fluid inclusion trails. Originally euhedral grains of ilmenite are first altered to aggregates of anatase + calcite then to titanite (Figure 5a-b), following the reaction proposed by Hansen, Reimink, & Harlov (2010) for low temperature conditions. Anatase is itself replaced by titanite, in textural equilibrium with chlorite flakes (Figures 5a-b). Anatase and titanite are systematically aligned with the chlorite flakes, within the S-planes. When they are folded to form kinks, anatase relicts are mainly preserved in the microfold hinges (Figure 5c). In some of the weakly deformed samples, titanite is the major Ti-bearing phase preserved (samples ZA16-119, B11-16, ZA16-77 and ZA16-84).

In weakly deformed samples showing millimetric fractures, biotite deformation and stretching along the main schistosity S is more pronounced (e.g. Figure 4e). Calcite is present in the matrix. Fractures 1-3 mm thick displace the folded chlorite flakes to form en-echelon microstructures (Figure 4e). These fractures are filled with secondary chlorite (ChlB)  $\pm$  white mica (Figure 4f). Sheets of ChlB are oriented parallel to the fracture walls in contrast to ChlA grains which are mainly perpendicular (Figure 4f). Furthermore, ChlB is rarely associated with biotite breakdown products as prehnite and Ti-bearing phases (Figure 4f). Quartz grains are both fractured and stretched, they exhibit undulose extinction and abundant fluid inclusion trails. Titanite is observed in the same microstructural position as in undeformed samples (folded within ChlA flakes). The microstructural position of anatase is instead more variable. Anatase

is observed: (1) as ~70  $\mu\text{m}$  sub-euhedral relicts in titanite cores at the rims of the ChlA flakes (as in the undeformed samples, type-1 Ant, Figure 4h, 5b-c, f-h and Figure S1) and (2) as grains 20-30  $\mu\text{m}$  in size not associated with titanite within ChlA flakes along the ancient biotite cleavages (type-2 Ant, e.g. Figure 4h, 5f-h and Figure S1). Locally, type-2 anatase is observed within ChlB-bearing fractures (e.g. ZA16-73, Figure 5i). Type-2 anatase of type 2 is often observed close to type-1 anatase. Magmatic accessory minerals such as apatite and zircon are fragmented and stretched along the S planes.

In mylonitic samples, the schistosity is defined by folded chlorite + white mica flakes and interconnected layers of white mica (Figure 4g). Flakes are folded up to kinks. Shear planes (C) form at high angle with the main schistosity S (Figure 4g-h). The kink axes are kinematically compatible with shear movement on the C planes. Quartz grains are partially stretched and most of them are fractured, with cracks subparallel to the C planes (Figure 4g). Within the grains, evidences of ductile deformation are observed such as deformation lamellae. A larger amount of fluid inclusions in quartz are observed with these samples compared to weakly deformed samples. In mylonites (ZA16-96, ZA16-98), only one type of anatase is observed (small anatase grains of type 2 predominate). In these samples, monazite grains, 10-40  $\mu\text{m}$  in size, were identified in mylonites (sample ZA16-98 and ZA16-88). These monazite grains are wrapped by secondary chlorite and white mica (suggesting post-magmatic origin). The largest grains of monazite (20-40  $\mu\text{m}$ ) (Mnz1) are lobate, and stretched along the C planes with fractures perpendicular to them and exhibit irregular grain boundaries, micrometric large fractures, patchy textures with bright and dark spots in BSE images and ‘inclusion-like dissolution figures’ (as described by Grand’Homme et al., 2018; Airaghi, Janots, Lanari, de Sigoyer, & Magnin, 2018, Figure 5c). Small monazite grains (~10  $\mu\text{m}$ ) with rounded shape share features with that of ZA16-88, aligned along the main foliation or within alteration halos marking the reaction front along secondary fractures subparallel to the C (Figure 5j). In sample

ZA16-98 monazite is locally Th and Si-enriched (tending towards a thorite composition, [inset in Figure 5i](#)).

In summary, the granitic rocks experienced a first transformation of the original magmatic mineral assemblage of  $Qz + Fs + Pl + Bt \pm Amph (+ Ilm + Ap + Zr \pm Aln)$  to  $Qz + ChlA + Ti\text{-phase} (Ttn \text{ or } Ant \text{ then } Ttn) \pm Pr \pm KFs$ . Zircon and titanite grains with anatase core (type-1 Ant) are stretched in the main schistosity and folded during shearing. They therefore predate any deformation stage. ChlB is rarely associated with secondary reaction products and helps to define the C-parallel fractures. It is considered to precipitate from a fluid during a second syn-kinematic (syn C planes) alteration event. The varying characteristics of anatase, only found in deformed samples, suggest that in these samples two generations of anatase may be preserved. That type-2 anatase is located within ChlA flakes along former biotite cleavage suggests that type-2 Ant grew after type-1 Ant on ChlA rims. The chloritization reaction front and replacement is indeed expected to progress from the grain boundaries to the core, along the biotite cleavages. The proximity of type-2 anatase to type-1 anatase grains indicates however transport scale of the anatase-forming elements limited to some dozen of  $\mu m$ . In sample ZA16-73 (discretely deformed). Type-2 Ant is observed in C-parallel fractures ([Figure 5i](#)). Type-2 Ant may have crystallized during the shearing. Mnz1 is affected by deformation and mainly observed within the main schistosity, while Mnz2 (and type-2 Ant, see below) are associated with C parallel fractures. Mnz2 is therefore syn C planes forming stage.

### 3.2 Samples from Triassic sediments and at the boundary between sediments and the granodiorite

At the brecciated contact between the Triassic sediments and the chlorite-quartz bearing vein in contact with the basement ([Figure 6a](#)), the Triassic sediments are composed of quartz, chlorite, white mica, Fe-oxides and clasts in a calcite matrix ([sample ZAL18-11](#)). The vein is

composed of mm-size quartz grains recrystallized by bulging and hosting a dense net of fluid inclusions, interlayered with elongate chlorite and white mica ( $\pm$  calcite) (Figure 6b). Along chlorite grain boundaries, abundant Fe-oxides, 20-40  $\mu\text{m}$  large anatase grains, monazite, REE-bearing carbonates and tourmaline are occasionally observed (Figure 6b). The textural aspect of monazite in sediments is similar to that of monazite in the basement (inset in Figure 6b).

The red-coloured, foliated pelitic rocks are comprised of white mica, chlorite and quartz grains on the scale of tens of microns ( $\pm$  detrital monazite, apatite and anatase, [samples ZAL18-12](#) and [ZAL18-13](#)). The veins are approximately 100  $\mu\text{m}$  thick, they opened at high angle with the foliation and are filled by elongate grains of quartz rich in fluid inclusions (in the core of the vein). Chlorite developed along the vein-host rock interface with long axes parallel to the vein opening direction (Figure 6c). Veins are stretched and displaced by 30-50  $\mu\text{m}$  secondary chlorite and quartz-bearing layers cross-cutting the foliation, forming ‘en échelon’ fractures (Figure 6c-d). Monazite in pelites forms euhedral grains 5-10  $\mu\text{m}$  in diameter, sometimes in association with Fe-oxides and xenotime at the interface between the veins and host-rock.

#### 4. ANALYTICAL AND COMPUTATIONAL METHODS

The chemical composition of metamorphic chlorite and white mica has been analysed with a CAMECA SX-FIVE electron probe micro-analyser (EPMA) at IStEP (Sorbonne Université). Point measurements were made under a 15 kV acceleration voltage and 10 nA beam current with a  $\sim 1\mu\text{m}$  beam size, in wavelength-dispersive spectroscopy (WDS) mode, using diopside (Ca, Mg, Si),  $\text{MnTiO}_3$  (Mn, Ti), orthoclase (K, Al), [hematite](#) (Fe), albite (Na) and  $\text{Cr}_2\text{O}_3$  (Cr) as standards for measuring the elements written in parentheses. The compositional variability of chlorite and white mica in different microstructural sites was characterised by element mapping using both the EPMA and a Zeiss SUPRA-55VP scanning electron microscope (SEM) at IStEP (Sorbonne Université). EPMA elemental maps were acquired in WDS mode at 100

nA beam current, 15 keV acceleration voltage with a 200 ms dwell time. SEM maps were acquired in energy-dispersive spectroscopy (EDS) mode at 15 keV acceleration voltage, 30 nA beam current with a dwell time of 256  $\mu$ s. SEM and EPMA maps were quantified with the software XMapTools (Lanari et al., 2014). The U, Th, Pb and REE contents of monazite were analysed with the JEOL-JXA-8230 EPMA at ISTERre (University of Grenoble), at 15 keV acceleration voltage, 200 nA beam current with a spot beam size. For each monazite analysis, a chemical U-Th/Pb age was determined and the average age of different populations of monazite (identified on the base of compositional criteria) was calculated with the software NiLeDAM. The analytical protocol and data processing are detailed in Appendix 1.

Titanite, anatase and zircon were dated *in-situ* by the U-Pb LA-ICP-MS technique at Trinity College, Dublin (Ireland), on the same thin sections as used for the microstructural and petrological studies. U-Pb ages were determined using a Photon Machines Analyte Exite 193 nm ArF Excimer laser-ablation system with a Helex 2-volume ablation cell coupled to an Agilent 7900 ICPMS. For titanite, zircon and anatase, 300 shots were ablated per analysis with a laser spot size of 24  $\mu$ m (Figure S1). The laser repetition rate and fluency were set at 15 Hz, 1.60 J/cm<sup>2</sup> and 11 Hz and 2.25 J/cm<sup>2</sup> for anatase/titanite and zircon respectively, and typically 50 analyses were obtained on each sample (usually 1-2 spots per grain) and plotted on a Tera-Wasserburg diagram (Tera and Wasserburg, 1972) with 2 $\sigma$  error ellipses, allowing determination of the initial Pb intercept on the <sup>207</sup>Pb/<sup>206</sup>Pb axis.

The raw titanite and anatase isotope data were reduced using the “VizualAge UcomPbine” data reduction scheme (DRS) of Chew, Petrus, and Kamber, (2014). The “VizualAge” DRS was employed for zircon data reduction. Common Pb in the titanite and rutile standards was corrected using the <sup>207</sup>Pb-based correction method. For unknowns, the initial Pb in titanite and anatase was determined from the upper intercept (y-intercept on the <sup>207</sup>Pb/<sup>206</sup>Pb axis) of the discordia line defined by the analyses on Tera-Wasserbutg Concordia.

The age for each population of grains was calculated from the lower intercept of the discordia line on Tera-Wasserburg Concordia. line with the Pb evolution model. Zircon ages were instead estimated by calculating the weighted average of  $^{206}\text{Pb}/^{238}\text{U}$  corrected ages (Table S3). The primary standards employed, the secondary standard ages and further details on the analytical procedure are reported in Supplementary Material S1. Titanite and anatase included in ilmenite were not dated due to their small size. When anatase core relicts were preserved in titanite grains (type-1 Ant), it was rarely possible to ablate separately relicts of anatase and their titanite host due to the small grain size (e.g. Figure S1). In anatase-dominated samples, where the bulk of grain was anatase, these analyses were classified and processed as anatase, in titanite dominated samples with only minor relict anatase the analyses were classified as titanite. The contribution of relicts of anatase to the calculated age was estimated by comparison with results from samples where the only anatase or titanite only were sampled. In sample where two types of anatase were observed, all anatase data were processed together. The existence of one or two population(s) of anatase based on the data interpretation was compared to microstructural observations.

Monazite ages were calculated from the EPMA U, Pb and Th contents. The associated detection limits were 90 ppm for Pb, 120 ppm for U and 115 ppm for Th. For each monazite analysis, a chemical U-Th-Pb age was determined (see Montel et al., 1996). When the Pb content was lower than the EPMA detection limit, a value of 90 ppm was used to estimate a maximum age.

The crystallization temperature and the minimum content of  $\text{XFe}^{3+}$  ( $\text{Fe}^{3+}/(\text{Fe}^{2+} + \text{Fe}^{3+})$ ) of each generation of chlorite in 23 selected samples were estimated using the Chl-Qz-H<sub>2</sub>O thermodynamic model of Vidal et al. (2006) from element abundances at a reference pressure of 3 kbar and H<sub>2</sub>O activity at fixed unit value. The absolute uncertainty on the crystallization temperature estimates is around 50°C (Vidal et al., 2006; Dubacq, Soret, Jewison and Agard,

2019), although the relative uncertainty between samples is likely lower (10-20°C). The semi-empirical thermometer of Bourdelle, Parra, Beyssac, Chopin, and Vidal (2013) formulated for low-temperature chlorite was used for comparison.

## 5. RESULTS

### 5.1 Composition of pre-kinematic and syn-kinematic chlorite and white mica

Chlorite generally exhibits compositional variation at the  $\mu\text{m}$ -scale with high variability in Fe, Mg and Al contents (especially in discretely deformed granites), as shown in Figure 7 (and Table S1). In samples collected east of Lake Urdiceto, two groups of chlorite are recognized. The first, **named Chl1**, is ubiquitous from undeformed granites (pre-kinematic) to mylonites, and **mainly observed in ChlA** flakes (Figure 7a). **It should be noted that Chl1 refers to a chemical composition while ChlA refers to the microtexture of chlorite (which do not necessarily correspond, e.g. Vidal et al., 2006; Airaghi et al., 2017).** Chl1 is Al-poor (2.2-2.4 apfu) and Mg-rich (1.7-2.5 apfu). **The second group of chlorites, Chl2, is mainly observed in syn-kinematic ChlB** (Figure 7a, c-d) **and exhibits higher Al content** (Al= 2.5-2.86 apfu) **and lower Mg content** (Mg= 1.5-1.7 apfu). The Fe content increases slightly from **Chl1** (2.15-2.3 apfu) to Chl2 (2.4-2.5 apfu). In undeformed samples, only homogeneous Chl1 **in chlorite flakes** is observed (e.g. sample ZA16-84). In the most deformed **samples, chlorite flakes (ChlA)** exhibit  $\mu\text{m}$ -scale Mg and Al zoning and portions of **Chl1 are** pseudomorphically replaced by Chl2. Chl1 is also found as relicts in ChlB in fractures, wrapped by Chl2 (Figure 7a). In samples collected west of Lake Urdiceto, Chl1 **in flakes** is Fe-rich (1.97-2.13 apfu) and Mg-poor (2.18-2.47 apfu) compared to Chl2 **in veins and along fractures** (Fe= 1.39-1.50 apfu, Mg= 2.83-2.95 apfu) (Figure 7b, c, e) while the Al content is typically constant (Table S1). A micron-scale zoning within Chl1 flakes is observed miming cleavage planes of the original magmatic crystal



(biotite or amphibole) in discretely deformed samples, while Chl2 within **ChlB within** fractures is homogeneous (Figure 7b). In mylonites, chlorite shows intermediate compositions (e.g. sample ZAL6-96 in Figure 7c) difficult to relate to a specific microtextural sequence due to extensive deformation. In the Triassic sediments, chlorite is Al-enriched compared to chlorite in the basement, but exhibits similar compositional trends (Figure 7c-e). Two groups are recognized in samples ZAL18-13 and ZAL18-12: one is Mg-depleted (1.7-1.97 apfu) and Al-enriched (2.90-2.92 apfu) and is observed in veins, the other is Mg-enriched (2.18-2.40 apfu) or Al-depleted (2.68-2.78 apfu) and is observed within the matrix (Figure 7c-e). Only the second group of chlorite is observed in sample ZAL18-11 (Table S1).

White mica in the granitic basement shows 55-80 % muscovite (*Ms*), pyrophyllite (*PrI*) content in the 0-20% range and up to ~30 % celadonite content (*Cel*, Figure 8a). White mica in fractures, veins and in the deformed matrix (syn-kinematic) exhibits lower muscovite (55-70 %) and higher (or similar) celadonite content (20-30 %) than white mica in chlorite flakes (pre-kinematic, 70-80 % muscovite, 10-20 % celadonite, Figure 8a). The composition of white mica in sedimentary samples is similar to that of **white mica from feldspar in basement samples** (Figure 8b), but **with lower variability**. While in samples ZAL18-12 and ZAL18-11 one single group of white mica is observed, in sample ZAL18-13 two groups are identified: white mica in the veins have higher celadonite contents (18-28%) than in the matrix (10-18%).

## 5.2 Thermobarometry of low-grade fluid-rock interaction events

Thermodynamic modelling was combined to empirical thermobarometry to distinguish the conditions of crystallisation of the different generations of chlorite and white mica possibly recorded by the restricted range of compositional variations. Crystallisation temperature calculated with the chlorite thermometers of Vidal et al. (2006) and Bourdelle et al. (2013) are reported in Figure 9a, and range between 180 and 350°C. The minimum content of  $XFe^{3+}$  in



400 chlorite calculated with the method of Vidal et al. (2006) ranges between 0.1 and 0.55, which  
 401 is realistic for low-T chlorite (Masci et al., 2019). The entire iron content was considered  
 402 divalent for the thermometer of Bourdelle et al. (2013) as recommended in that study.  
 403 Calculated temperatures for all groups of chlorites are in the same range, with small but  
 404 systematic differences between Chl1 and Chl2. In samples recording two compositional groups  
 405 of chlorites (that correspond to pre and syn-kinematic grains), where Fe variations prevail on  
 406 other element variations (ZA16-82, B11-19, ZA16-78), Chl1 records higher temperatures (220-  
 407 320°C) than Chl2 (180-250°C). In samples where dominant chemical variations involve Al and  
 408 Mg (ZA16-126, ZA16-73, B10-32), Chl1 records lower temperatures (170-280°C) than Chl2  
 409 (230-350°C, Figure 8a). In other samples (ZA16-133, B10-31), where two compositional  
 410 groups of chlorite were observed, calculated temperature cover the entire temperature range  
 411 estimated for all samples. Undeformed granite samples preserving only Chl1 (e.g. ZA16-79,  
 412 B11-16, ZA16-117) record the highest range of temperatures (280-350 °C). Crystallisation  
 413 temperatures calculated for chlorite in mylonites (e.g. ZA16-96, ZA16-98, ZA16-128, ZA16-  
 414 97) are intermediate between the Chl1 and Chl2 crystallisation temperatures. Two ranges of  
 415 temperatures were also obtained for chlorite in sedimentary samples (ZAL18-12). The highest  
 416 temperatures (240-350°C) are generally associated with chlorite in veins, while lowest  
 417 temperatures (180-280°C) are mostly associated with chlorites in C planes (with variability,  
 418 especially for samples collected Est and West of the Lake of Urdiceto, Fig. 1c). Only one range  
 419 of chlorite temperatures (Chl2, 200-300°C) is observed within the vein of sample ZAL18-11.  
 420 To test for the statistical validity of the two temperature intervals (240-350°C and 180-280°C),  
 421 3000 temperatures were randomly sampled from the dataset calculated with the thermometer  
 422 of Vidal et al. (2006) assuming a Gaussian error of  $\pm 30^\circ\text{C}$  (Figure 9b). In the basement, two  
 423 main peaks at 260 and 330°C persist. Scattered values at low-T conditions are attributed to

modelling artefacts due to  $\text{Fe}^{3+}$  overestimation and/or to departure of some chlorite compositions from equilibrium with assumed unit activity for quartz and water.

The moderate celadonite contents of white mica (accounting for the Tschermark substitution only) suggest crystallization pressures in the range 1-4.5 kbar following the calibration of Massone and Schreyer (1988) (Figure 9c), as opposed to sub-surface hydrous alteration of feldspar only, which would favour pyrophyllitic substitution (Dubacq, Vidal, & De Andrade, 2010). Following this calibration, the higher celadonite content (and Si apfu content) of white mica in fractures, veins and shear bands indicates higher pressure conditions than in white mica growing from feldspar or from biotite (white mica in flakes, Figure 9c).

### **5.3 *In situ* U-Th/Pb dating of magmatic zircon and hydrothermal anatase, titanite and monazite**

Results for titanite, anatase and monazite dating are shown in Figure 10a-c and summarized in Table 1; the raw isotopic ratios and age data for zircon, titanite and anatase are provided in Table S3. The entire geochronological dataset is combined with previous literature age constraints of metamorphic events, derived from other localities of the Axial zone in Figure 10d. The composition of monazite together with all concordias for zircon, titanite and anatase are provided in Figure S2. Zircon analyses yield weighted mean Concordia ages at 300-310 Ma (Figure 10d and f). Some zircon analyses, especially in sample ZA16-119, exhibit Pb loss and broadly define a discordia line intercepting the Concordia at c. 285-290 Ma (see Figure S1).

Titanite grains contain on average 16 ppm of U, 1.7 ppm of Th and 50 ppm of common Pb, and exhibit a Th/U ratio of 0.1 with ages spanning from  $336 \pm 12$  to  $313 \pm 11$  (Figure 10a and d). Titanite in ZA16-84 provides the age constraint with the lowest uncertainty ( $313 \pm 11$ , MSWD of 1.1, Figure 10a) and exhibits the lowest common Pb content (10 ppm) and the highest Th/U ratio (0.20). Anatase contains on average lower amounts of U (8 ppm) and common Pb

(24 ppm), and higher Th contents (3.4 ppm) than titanite, with Th/U ratios of 0.4, with ages from 301 to 48 Ma (Figure 10b and d). The age of anatase is difficult to constrain because of high common Pb and low radiogenic Pb contents. When possible, two Tera-Wasserburg concordia lower intercepts for anatase U-Pb age data were defined for each sample, delimiting the possible youngest and oldest grain populations (e.g. Figure 10b). In this case, youngest ages cluster at *c.* 30-80 Ma while oldest ages cluster at *c.* 240-280 Ma (Figure 10b, d). The mylonitic granite ZA16-96 exhibits the young age population only (Tera-Wasserburg concordia lower intercept of  $39 \pm 8$  Ma, Figures 10c and S1), despite the low variability of the radiogenic U/Pb ratio.

Patchy monazite in samples ZA16-98 and ZAL18-11 shows low and variable U and Th contents (Figure 10e and Table S2), typical of low-temperature secondary monazite (Rasmussen & Muhling, 2007; Janots, Berger, & Engi, 2011). The U-Th/Pb ages (with Pb > EPMA detection limits of ~100 ppm) range between 180 and 325 Ma (Figure 10c). In both samples, Pb-depleted domains (Pb < EPMA detection limits despite Th contents up to few wt%, Table S2) are observed within Th-depleted monazite grains, indicating late partial replacement of monazite grains by recrystallization and dissolution-reprecipitation (Figure 10e). The oldest ages generally correspond to monazite with relatively high Th content ( $\text{ThO}_2 > 2.4$  wt %) and variable U content ( $0.04 \text{ wt}\% < \text{UO}_2 < 1.0 \text{ wt}\%$ ). They cluster around  $254 \pm 6$  Ma. A second group of monazite has a lower Th content ( $\text{ThO}_2 < 1.9 \text{ wt}\%$ ), variable U content ( $0.01 \text{ wt}\% < \text{UO}_2 < 1.9 \text{ wt}\%$ ) and provides an age of  $196 \pm 18$  Ma. In both samples ZA16-98 and ZAL18-11 young ages are estimated from the Pb-depleted domains (Pb < detection limits). Assuming a Pb content equal to the EPMA detection limit (~90 ppm), a maximum age for this late stage crystallisation has been calculated at *c.* 100 Ma in sample ZA16-98 and at *c.* 20 Ma in sample ZAL18-11 for the domains with the highest Th ( $\text{ThO}_2 = 7.6 \text{ wt}\%$ ) and U contents ( $\text{UO}_2 = 0.9750 \text{ wt}\%$ ) (Figure 10c). Cenozoic ages of *c.* 50 Ma have also been estimated in sample ZA16-98

from thorite-monazite domains. No ages could be obtained for monazite from the sedimentary samples due to their low U, Th and Pb contents.

## 6. DISCUSSION

### 6.1 Evaluation of geochronological results

Estimated crystallisation temperatures are far below the closure temperature of Pb diffusion in rutile (580-630°C), titanite (575-700°C), monazite (~800 °C) and zircon (~900 °C, Rubatto, 2017; Engi, 2017 and references therein). Therefore, U-Th/Pb dates are interpreted as crystallisation ages. Zircon is dominantly of magmatic origin as attested by its microtextures. Concordant zircon ages, inferred to bracket the timing of the Bielsa pluton emplacement at 300-310 Ma (Figure 10d and Table 1), are in agreement with previously published ages (Vacherat et al., 2017). Zircon ages therefore constrain the upper limit of the first alteration event. Discordant ages defining a chord with an intercept at c. 290 Ma in sample ZA16-119 (Figure S1) derive from sampling of metamictic zircon domains, characterized by decreasing crystallinity, Pb loss and variable incorporation of common Pb. Since metamict domains show typical textures of dissolution-reprecipitation under low-T conditions (Geisler et al., 2003) and are observed in undeformed samples, the c. 290 Ma age may indicate re-opening of the system during the early pre-kinematic fluid-rock interaction, started shortly after the pluton emplacement, in Late Variscan times.

Titanite ages are less accurate but cluster within uncertainty of the zircon ages, at c. 300 Ma (Late Variscan) (Figure 10d and Table 1). Some of the titanite ages are older than the corresponding zircon ages from the same sample. The titanite Discordia line on Tera-Wasserbourg Concordia diagram is well constrained due to the large variation in U:Pb ratio of the titanite grains (Figure 10a and Figure S2). Therefore, the titanite ages marginally older than

their corresponding zircon ages may originate from local incorporation of radiogenic Pb at the time of titanite crystallization (see also Essex and Gromet, 2000). The  $^{207}\text{Pb}/^{206}\text{Pb}$  initial ratio of metamorphic titanite has been shown to vary up to 2% in the same sample (Kohn, 2017), and is often significantly lower (i.e. more radiogenic) than the crustal evolution model of Stacey and Kramers (1975). This signs the incorporation of radiogenic Pb from the breakdown of a U-rich mineral phase such as rutile or anatase, anatase being observed here as the most common titanite precursor.

The U/Pb ages obtained for anatase are less well constrained than the titanite due to higher common Pb, lower radiogenic Pb contents and the smaller spread in U-Pb ratio of the anatase grains. Calculated ages range between 40 Ma and 280 Ma. Anatase does not record the magmatic stage since it is observed to replace magmatic ilmenite. If type-1 Ant or titanite recrystallize into type-2 Ant, inter and intra-grain variations in the radiogenic Pb and U content could be inherited from the parent mineral given the small transport scales for anatase-forming elements deduced from microtextural evidence (see section 3.1). Such variations and possible incorporation of type-1 Ant in spot ablations of titanite (see section 4) contribute to the large spread of the anatase ages (e.g. samples ZA16-79, ZA16-73). However, a recurrently young signal of *c.* 40-80 Ma is exclusively observed only in samples with both types of anatase and in mylonites. As solid-state Pb diffusion can be excluded due to the low metamorphic grade, the youngest U-Pb anatase ages likely indicate partial (re-)crystallization of the smallest anatase grains (type-2 Ant), in agreement with microtextural observations. In addition, the upper limit of the range of anatase ages is the youngest in samples with both types of anatase: This suggests mixing at a smaller scale than laser beam size between older titanite-anatase and new anatase. The two age end-members are shown on Figure 10d for all anatase-bearing samples. Monazite is unlikely to record the magmatic stage since (1) magmatic allanite and apatite incorporate the rare earth elements and phosphorous necessary for monazite crystallization, (2)

monazite is observed to replace magmatic allanite or apatite and (3) the oldest monazite ages are younger than the zircon ages. Monazite ages in both samples ZA16-98 and ZAL18-11 indicate a series of events at *c.* 250 Ma, 200 Ma, and possibly < 50 Ma. This range of ages suggests successive episodes of partial dissolution-reprecipitation, as also shown by the patchy textures and the dissolution figures of monazite grains (Figures 5c and 6b). The mineral assemblage corresponding to the monazite ages of *c.* 200 Ma remains difficult to identify as textural and chemical evidences is lacking. The ages of 190-250 Ma obtained in monazite of chlorite-bearing veins in sediments indicate that monazite grains were likely inherited from the underlying basement and partially re-crystallized during vein opening and fluid circulation soon after sediments deposition in Triassic times.

## 6.2 Timing and conditions of fluid-rock interactions and deformation

Detailed microstructural and petrological observations show a poly-phase alteration history in the Bielsa basement at temperatures below 350°C. Within this temperature range, a first fluid-rock interaction event is related to the breakdown of the original magmatic assemblage and the growth of Ttn, Chl1, anatase (type-1 Ant) at 270-350°C. This alteration event predates all deformation stages since the earliest deformation phase deforms this mineral assemblage and the alteration event is also observed in undeformed samples (e.g. Figure 4a-b). During the first alteration event, the source of Al and Ca for chlorite and titanite ( $\pm$  prehnite) growth is the contemporaneous breakdown of plagioclase and the albitization of alkali-feldspar (always largely consumed), irrespective of the strain intensity. Calcium may also derive from external fluids as attested by calcite growth within weakly deformed granite matrix. Titanite, zircon, anatase and oldest monazite ages allow bracketing the timing of the early alteration(s) to 230-300 Ma (late to post-Variscan). This age range is in agreement with  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of biotite of *c.* 280 and 250 Ma obtained in the Bielsa and Maladeta massifs respectively (Jolivet et al., 2007).

The second fluid-rock interaction event is related to the syn-kinematic growth of Chl<sub>2</sub> during the formation of C-S structures (see section 3) at ~200-280°C. The pervasive schistosity, kinking, shearing and fracturing are likely to have occurred at the same time since they are kinematically compatible. The S planes are observed in both the basement and in the Triassic sediments (see section 2). The S-forming stage is therefore post-late Triassic in age at least.

In such deformed samples, the youngest ages are yielded by anatase (in samples bearing both types of anatase) and by monazite; this suggests that deformation triggered the partial recrystallization of anatase and monazite. The youngest anatase ages only (*c.* 40 Ma) and the youngest monazite ages (*c.* 50 Ma) are obtained in mylonites (ZA16-96 and ZA16-98). This observation suggests that the mylonitization related to the deformation stage likely occurred between 40 and 70 Ma. These ages are in agreement with Rb-Sr ages of *c.* 48 Ma obtained for the (re)activation of mylonitic bands in the Néouvielle massif (~ 15 km to the northwest of Bielsa, Wayne & McCaig, 1998). In sample ZA16-79 an age population at *c.* 120 Ma is observed, but no clear textural relationships are identified, while the large uncertainties mean it Eocene ages.

Chlorite temperatures calculated with the method of Vidal et al. (2006) and Bourdelle et al. (2013) are consistent despite differences in how they employ the oxidation state of Fe. The calculated range of temperatures (200-350°C) is also consistent with hydrothermal conditions typically associated with the appearance of prehnite and titanite in the cleavages of biotite (e.g. Eggleton & Banfield, 1985; Morad, Sirat, El-Ghali, & Mansurbeg, 2011; Yuguchi et al., 2015) and with temperatures calculated for the overlying sediments, suggesting that fluids were freely circulating between the basement and the overlying sediments. In details, thermometric results indicate that the pre-kinematic greenschist-facies metamorphism occurred at higher temperature (270-350°C) than later syn-kinematic fluid-rock interaction (200-280°C, Figure 9b), with spatial variations (east and west of Lake Urdiceto, Figure 9a) due to local



variations in fluid composition. The systematic differences between temperatures estimated for Chl1 and Chl2 support however the existence of two different fluid-rock interaction events.

The moderate celadonite content of white mica, especially in fractures, veins and shear bands (Figure 8a and c) suggests crystallization at a pressure of 1-5 kbar (1 - 4.5 kbar, following the formulation of Massone and Schreyer, 1988, Figure 9c and below 3 kbar according to Cathelineau et al., 1986 for hydrothermal alteration in granites). No paragonite nor margarite components are observed within our white mica dataset. Pyrophyllite substitution, which increases the Si content of muscovite, is not predominant compared to the Tschermak substitution (Figure 8a). Increasing pyrophyllite content in sample B11-31 implies crystallization during continuous cooling (Dubacq et al., 2010). Fluid inclusion trapping pressures in the range 2-5 kbar are reported by Henderson and McCaig (1996), consistent with pressure estimates from white mica in mylonite veins (Wayne & McCaig, 1998). The lowest pressure values of ~ 2 kbar are consistent with the maximum burial depth estimated for the Bielsa (Jolivet et al., 2007; Bellahsen et al., 2019).

This low-grade petro-chronological dataset allows the timing of low-grade metamorphism and deformation to be discussed in the light of the Variscan and Alpine orogenic cycles, with major implications for the crustal rheology and the evolution of the deformation style in granites.

### 6.3 Pre-orogenic alteration and implications for crustal softening prior to shortening

Petro-chronological results and microstructural analyses show that Late to post-Variscan lower greenschist-facies metamorphism in the Bielsa massif transformed an initially strong assemblage made of plagioclase, K-feldspar (forming together close to half of the primary modal composition) and amphibole into weaker, hydrated minerals such as white mica and



chlorite, without associated deformation (as suggested by Bellashen et al., 2019). The breakdown of feldspar to white mica decreases by up to two orders-of-magnitude the sustained shear stress (at a constant strain rate) at 400°C, lowering the depth of the brittle-ductile transition by at least a third (Wintsch et al., 1995; Gueydan et al., 2003). In the Bielsa massif, pre-orogenic [sub to lower greenschist-facies](#) metamorphic reactions [have two effects: they enhance grain size reduction \(e.g. from magmatic feldspars to minute white micas\) and also replace strong minerals such as feldspar and amphibole with mechanically weaker phyllosilicates](#) (e.g. Shea & Kronenberg, 1993). [Both processes are known to result in enhanced softening of the granitic rocks \(e.g. Fitz Gerald & Stünitz, 1993; Wintsch et al., 1995; Oliot, Goncalves, Marquer, 2010\).](#) Early pre-kinematic alteration therefore considerably softened the granite at least [150 Ma](#) before the major Alpine shortening phases. Furthermore, the massive growth of pre-kinematic and pre-Alpine white mica and chlorite indicates high fluid-rock ratios during Late-to post-Variscan times and may strongly influence the water availability in the rocks at the grain boundaries during deformation. This has been shown to have major effects on the mechanisms of strain accommodation in other major phases as quartz (e.g. Palazzin et al., 2018) and hence impact the deformation style.

Sericitisation of feldspar and chloritisation of biotite is observed to increase with deformation. This suggests that granite alteration continued during syn-kinematic Alpine shortening. In mylonites, syn-kinematic chlorite and white mica partly replace the pre-kinematic chlorite and mica grains, this time without needing huge supplementary amounts of external fluid. Consequently, in the latter fluid-rock interaction event, there is no evidence for additional large-scale reaction-driven softening outside mylonitic zones, consistent with observations reported for the [Néouvielle](#) massif (~ 15 km to the northwest, Wayne & McCaig, 1998). The crystallisation of new phyllosilicates and the larger amount of fluid inclusions in quartz in fractured and mylonitic samples as well as the partial age resetting [up to ~40 Ma](#) close

to shear zones also appear to indicate progressive localisation of metamorphism with strain localisation.

Zones of fractures and faults indicate that granitic rocks were also deformed by frictional behaviour, as commonly observed at temperatures of 200-350°C (e.g. Copley, 2017). The crystallization of phyllosilicates during a pre-orogenic alteration event may weaken fault zones by at least 30% as phyllosilicates have much lower coefficients of friction than undeformed and unaltered crystalline rocks (e.g. Kaduri, Gratier, Renard, Çakir, & Lasserre, C., 2017; Copley, 2017). The pre-existence of phyllosilicate in the Bielsa basement therefore appears to have generated a network of weak rocks with low friction coefficient resulting in their distributed deformation.

#### **6.4 Effect of the early alteration on deformation patterns at field scale**

The pervasive schistosity (S) observed within the Bielsa massif along the studied transects indicates that the deformation is distributed at the scale of the massif (Figure 1b). The existence of mylonitic corridors shows a phase of strain localization with variations in the sense of shear at the kilometric to decametric scale, but their high density also results in a distributed deformation at the massif scale. At Bielsa, both S and C forming stages post-date the Late to post-Variscan pervasive alteration that softened the basement. In the Maladeta massif, (50-60 km to the northeast), less pervasive pre-kinematic alteration is observed as well as localized deformation and lower density of mylonitic corridors (Leblanc, Gleizes, Lespinasse, Olivier, & Bouchez, 1994). This indicates that pre-orogenic crustal softening controlled the deformation patterns observed on a outcrop scale, in particular the frequency of mylonitic bands the location of faults and of fractures.

In the Bielsa massif, strain localization in mylonitic bands may have occurred during the intense folding of the basement and the sedimentary cover in the Eocene as indicated by the

young ages from the mylonites. During this stage, the re-activation of steep faults may have served as fluid pathways and triggered alteration. Interfaces between differently-altered domains formed different phase strength contrasts. Consequently, ductile strain and reactions interacted positively to produce narrow ductile shear zones (as described by Holyoke & Tullis, 2006). Furthermore, deformation at this stage may strongly influence the breakdown on residual feldspar to muscovite (e.g. Knipe & Wintsch, 1985), as attested by the greater amount of white mica observed in mylonites compared to weakly and undeformed samples.

The youngest ages obtained in this study (*c.* 40 Ma) are older than the activation of the Gavarnie and Guarga thrusts (Figure 1b), in the hanging and footwall of the Bielsa unit, dated at 32-36 Ma et 20-30 Ma respectively (e.g. Bosch et al., 2016; Elmola et al., 2018) and similar to the age of mylonitization in the Néouvielle massif (Wayne & McCaig, 1998). This may indicate that the distributed shortening in Bielsa and at a larger scale predates the localization of the strain along some of the major thrust of the Axial zone. These findings are consistent with the distributed / localized modes of shortening documented in the external Western Alps (Bellahsen et al., 2014), in the central Alps (Wehrens, Baumberger, Berger & Herweg, 2017) and in the Longmen Shan where pre-kinematic and a syn-kinematic greenschist-facies metamorphic events were also recognized (Airaghi et al., 2017b), indicating that they might be typical of the evolution of basement massif in the external domains of the orogenic wedges.

## 6.5 Onset and preservation of early alteration in granitic basement

Late to post-Variscan fluid-rock interaction took place on the scale of the Axial zone as metamorphic reactions similar to those observed in the Bielsa massif are found in other crystalline massifs in the Pyrenees (e.g. Maladeta, Néouvielle, Col de Jau; Cathelineau, 1986; Boutin et al., 2016). The early alteration stages may be linked to protracted magmatic activity recorded in the Pyrenean domain throughout the entire Permian (Denèle, Paquette, Olivier, & Barbey, 2012). Late Variscan magmatic activity has also been invoked as the cause of

hydrothermal alteration in the French Massif Central (Cathelineau, 1986; Turpin, Leroy, & Sheppard, 1990). Permian to Triassic ages similar to those obtained for fluid-rock interaction events in the Bielsa massif have also been documented in the Variscan basement of the Eastern Iberian Central System and in NE Spain by fluid inclusion and isotopic studies (Tornos, Delgado, Casquet, & Galindo, 2000 and references therein). The associated hydrothermal alteration in these cases is related to hydrothermal cells formed during extensional tectonic events rather than to plutonism (Tornos et al., 2000; Cardellach, Canals, & Grandia, 2002). In the Bielsa massif, high fluid-rock ratios have been proposed to result from ingress of seawater and meteoric fluids during the extensional phase following the Variscan orogeny (McCaig, Tritlla, & Banks, 2000). This is consistent with the fact that the Bielsa basement was exposed at the surface before or during the Permian, as attested by the erosional unconformity between the basement and its sedimentary cover. The preservation of early alteration features in granites over two orogenic cycles (Variscan and Alpine) implies that the basement remained at low grade conditions for over 200 Ma. In the Pyrenees, the main post-Variscan metamorphic phase related to fluid circulation is dated at 110 Ma (e.g. Boutin, 2016). Although Cretaceous ages were obtained for samples which contain both types of anatase, the large U/Pb age uncertainties for this time period in our petro-chronological dataset mean that strong evidence for extensive fluid circulation, mineral replacement and deformation during Cretaceous times is lacking. This is in contrast to the eastern Pyrenees where a hydrothermal event characterized by newly formed rutile and titanite associated with Cretaceous rifting overprints the ‘post’-Variscan hydrothermal alteration assemblages (Figure 10d; Boutin et al., 2016; Fallourd et al., 2014). This may indicate that, within the Pyrenean belt, metamorphism related to rifting has only weakly affected the southern part of the Axial zone.

## 7. CONCLUSIONS

699 The granitic basement rocks in the southern Axial zone of the Pyrenees (Bielsa massif) acted  
 700 as reactive rocks at low temperatures ( $T < 350\text{ }^{\circ}\text{C}$ ) over a long (*c.* 300 Ma) [polyphase history](#).  
 701 [At an outcrop scale, the Bielsa pluton and the Triassic sedimentary cover exhibit a pervasive](#)  
 702 [N-dipping schistosity, folded or associated to steep C planes localized within a dense network](#)  
 703 [of mylonitic bands. Within the granitic basement, partial mineral replacement and](#)  
 704 compositional variations at the micron-scale record [an extensive](#) fluid-rock interaction event at  
 705  $\sim 270\text{-}350^{\circ}\text{C}$  in Late to post-Variscan times (230-300 Ma), [as indicated by the titanite, anatase](#)  
 706 [and zircon U/Pb ages dataset](#). This event is ubiquitous and particularly well preserved in the  
 707 less deformed areas of the massif. It is responsible for pre-kinematic (pre-Alpine) plagioclase  
 708 and amphibole [replacement with growth of](#) phyllosilicates, some tens of million years after  
 709 pluton emplacement. A second [syn-kinematic](#) fluid-rock interaction event is marked by the  
 710 (re)crystallisation of phyllosilicates at  $\sim 200\text{-}280^{\circ}\text{C}$  and is [related to the formation of](#) mylonitic  
 711 corridors and [fractures parallel to the C shear planes](#). [In the most deformed samples, despite the](#)  
 712 low radiogenic Pb content, monazite and anatase U-Th/Pb ages [systematically show a young](#)  
 713 [age component at 40-70 Ma](#), coeval with the Alpine/ Pyrenean deformation in the southern  
 714 Axial zone [and related to the second alteration event](#). As the strength of phyllosilicate-rich  
 715 material is lower by up to an order-of-magnitude than that of the original granite, the granitic  
 716 massif was significantly softened (and hydrated) at least 150-200 Ma before the major Alpine  
 717 shortening phase. The dense network of mylonites in the Bielsa pluton resulted in distributed  
 718 deformation at the massif scale before the localization of the strain along the major thrusting  
 719 systems of the Axial zone. Pre-orogenic crustal softening controlled the deformation patterns  
 720 where strain and shortening localized during successive deformation events. Pre-orogenic  
 721 greenschist-facies metamorphism is often poorly characterized compared to higher-grade  
 722 metamorphic domains in mountain belts. The case of the Bielsa massif shows that moderate  
 723 analytical effort can provide valuable information allowing for a better constraints on the

rheological and thermobarometric evolution of basement rocks during the orogenic cycle, even at low-grade conditions.

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## SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for  
this article.

Description Supinfo.doc/x

**Appendix S1.** Analytical methods for geochronology and monazite analysis

**Figure S1.** Example of location of laser spot for zircon, anatase and titanite dating.

**Figure S2.** Tera-Wasserburg diagrams for all analysed anatase, titanite and zircon. Concordia-discordia diagrams for zircon.

Dataset.xls/x

**Table S1.** Representative chemical composition of chlorite and white mica.

**Table S2.** Representative chemical composition of monazite in samples ZA16-98 and ZAL18-11.

**Table S3.** Original isotopic data for zircon, titanite and anatase. Graphs represents weighted mean zircon ages.

# FIGURE CAPTION

**Figure 1** Geological maps and cross section. (a) Schematic structural map of the Pyrenees, modified from Román-Berdiel, Casas, Oliva-Urcia, Pueyo, and Rillo, 2004. Red square: Bielsa, N: Néouvielle, M: Maladeta, J: Jau. (b) Schematic structural cross section of the Axial Zone (modified from Jolivet et al., 2007). Yellow stars indicate limits of the area where pervasive alteration of the original granite has been documented. Black rectangle denotes the studied area. (c) Geological map of the studied area. (d) Cross sections along transects AA' and BB'.

**Figure 2** Field structures around Lake Urdiceto. (a) Mylonitic corridor along the transect BB' of Figure 1c. White: schistosity (S), yellow: shear planes (C). (b) Second example of mylonitic corridor a few hundred meters eastward of transect BB', at the contact with the Triassic sediments. Schistosity (S, filled white lines) is subparallel to S-dipping shear planes (C, marked in yellow) due to high strain. (c) Mylonitic bands within the basement with C planes varying from S-dipping to N-dipping. (d) N-dipping shear planes in a mylonite at the contact between

the basement and the sedimentary cover. (e) Enlarged view of mylonitic granite (see panel a for location). (f) Enlarged view of weakly deformed (but altered) granite (see panel a for location).

**Figure 3** Field structures in the Triassic sediments. (a) Unconformity between the basement and the Triassic sediments. (b) Chlorite-quartz bearing veins at the contact between the basement and the basal breccia in the Triassic sediments. (c) Two generations of chlorite-quartz bearing veins within Triassic sandstones and pelites.

**Figure 4** Photomicrographs (a, c, e and g) and backscattered electron images (BSE) (panels b, d, f and h) of granitic basement with increasing deformation. Abbreviations are from Whitney & Evans (2010), except Wm: white mica; (a) Undeformed but altered granite; (b) BSE image of a Chl + Wm + Ttn pseudomorph after Bt; (c) weakly deformed and altered granite with dark Chl-Wm pseudomorphs after Bt folded to form kink bands; (d) BSE images of a kinked Chl flake; (e) weakly deformed sample with opening fractures. Chlorite flakes are cross cut by secondary mm-size fractures. (f) BSE image of a Chl + Ttn flake after Bt (Bt relicts still visible), cross cut by a fracture filled with secondary chlorite; (g) mylonite; (h) folded Chl + Wm + Ant flake cross cut by a secondary fracture in a highly deformed sample. Two types of anatase grains are recognized.

**Figure 5** Backscattered images of accessory minerals in the granitic basement. (a) and (b) magmatic Ilm breaking down to Ant + Cal, then to Ttn. (c) Anatase 1 folded within a Chl flake and replaced by Ttn. (d) Magmatic zircon (core) with metamict rims (low CL intensity) in sample ZA16-119. (e) Chlorite flakes (ChlA) with type-1 Ant cross cut by ChlB-bearing fractures with type-2 Ant (sample ZA16-73). (f) Type-2 Ant rimming titanite after anatase

(type-1 Ant, preserved in the core of titanite). (g) Chlorite flake (ChlA) in sample ZA16-79 with both types of anatase. (h) Relationships between titanite and anatase in sample ZA16-128. (i) Monazite in sample ZA16-98. The inset image shows the patchy and porous aspect of the monazite grains. (j) Monazite in reaction halos around fractures in sample ZA16-88.

**Figure 6** Macro- and micro-scale petrography of the Triassic sediments. (a) Hand sample collected at the boundary between sediments and the granitic basement (ZAL18-11). (b) Backscattered electron image of panel a, showing the occurrence of anatase, Fe-oxides and Mnz within neocrystallized Chl and Wm. The inset show the patchy texture of monazite grains. (c) Chlorite-bearing veins and shear planes forming ‘en-echelon’ microstructures in sample ZA16-12. (d) Two generations of chlorite (in veins and shear planes) in samples ZA16-12 (zoom of panel c). ChlA and ChlB refer to chlorite flakes and chlorite in fractures/veins respectively but may be different in origin to ChlA and ChlB observed in the basement.

**Figure 7** Chemical composition of chlorite. (a) Quantified SEM map of  $\text{Al}_2\text{O}_3$  content in chlorite in sample B10-31 (mylonite). (b) Quantified SEM map of FeO content in chlorite of sample ZA16-82 (fractured sample). (c) Elementary Al vs Mg (%) content of all analysed chlorites; (d) Trends and compositional groups identified in chlorite in samples collected east of Lake Urdiceto; (e) Trends and compositional groups identified in chlorite in samples collected west of Lake Urdiceto.

**Figure 8** Chemical composition of white mica. (a) Compositional triangular plot and trends for white mica in the basement. (b) Compositional ternary diagram of white mica in the sedimentary samples. Mus: muscovite, Cel: celadonite, Pyr: pyrophyllite.



**Figure 9** Thermobarometric results. (a) Chlorite temperatures calculated with the method of Vidal et al. (2006) (circles) and Bourdelle et al. (2013) (rectangles). (b) Monte Carlo simulation for the temperature dataset calculated for basement chlorite (3000 iterations, see the text for details). (c) Pressure range estimated from the celadonite content in white mica, following the calibration of Massonne and Schreyer (1988). This calibration does not consider the pyrophyllite content in white mica, as it is the case in the Bielsa granite. Pressure values should therefore be considered as minimum values.

**Figure 10** Geochronology results. (a) Representative Tera-Wasserburg concordia lower intercept age defined by titanite analyses in an undeformed sample (ZA16-84). (b) Tera-Wasserburg Concordia lower intercept ages defined by various anatase populations (red: old, blue: young) in a deformed sample (ZA16-128). (c) Frequency distribution of monazite ages. Note that youngest monazite ages are estimated from Pb depleted domains (Pb < EPMA detection limits of ~100 ppm) and monazite-thorite domains (see the text for details). Note the ages calculated for domains where Pb is below the EPMA detection limit are maximum ages. (d) Summary of geochronological results (this study) integrated with previously published data for metamorphic events in the Axial zone. U-Pb Ant-Ttn indicate the ages obtained for analysis where a titanite locally preserved anatase cores (type-1 Ant, see the text for details). (e) U and Th content of monazite in sample ZAL18-11. (f) Probability density plot of all zircon ages for samples ZA16-84 and ZA16-119 (2 $\sigma$  error).

**Table 1** Summary of sample descriptions and ages.

185x189mm (300 x 300 DPI)

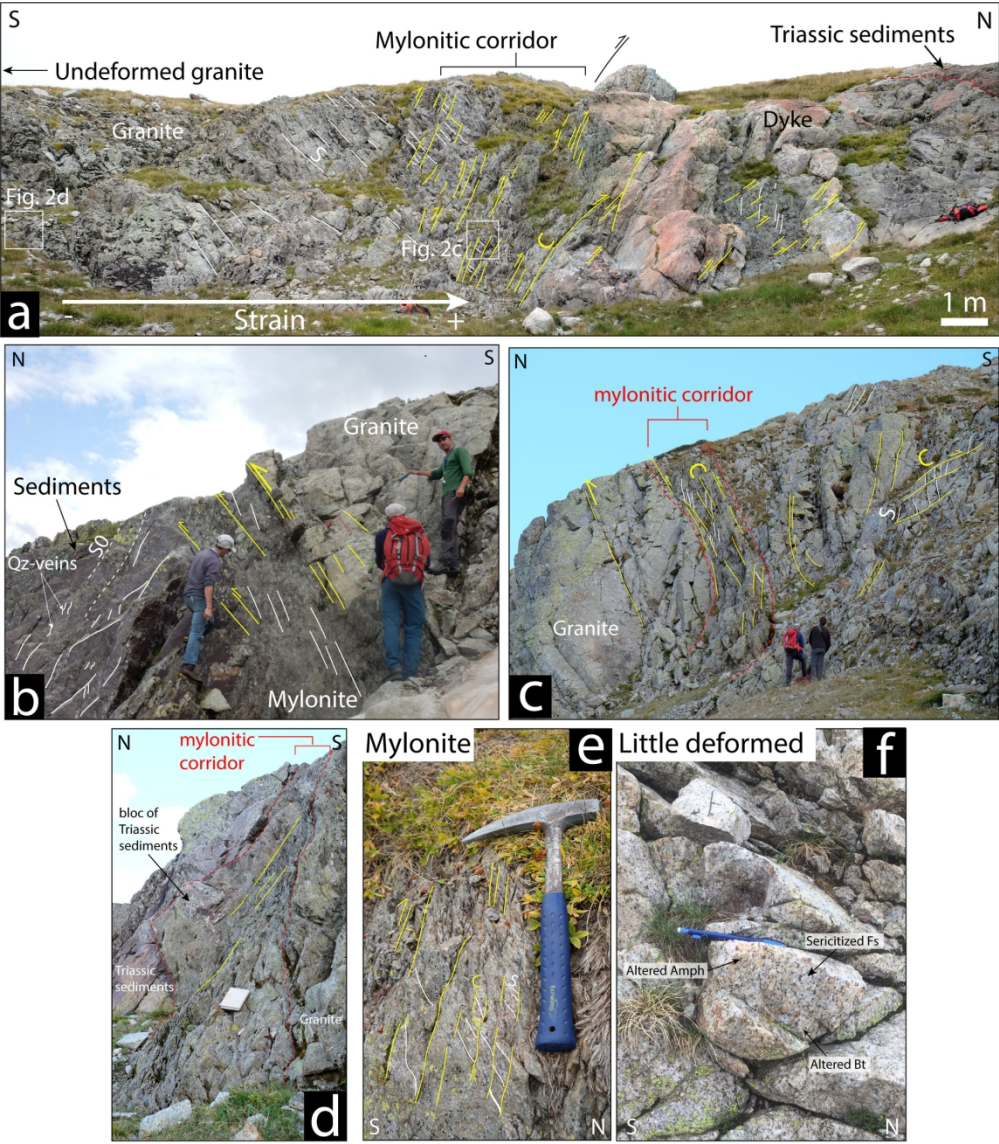


Figure 2. Field relationships within the cristalline basement

180x207mm (300 x 300 DPI)

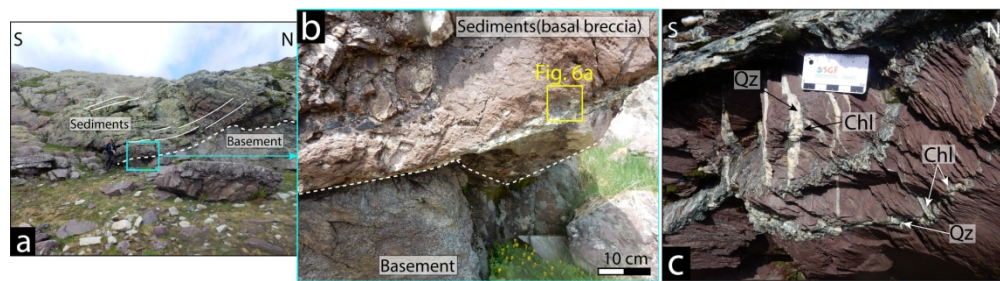


Figure 3. Field relationships within the Triassic sediments

190x53mm (300 x 300 DPI)



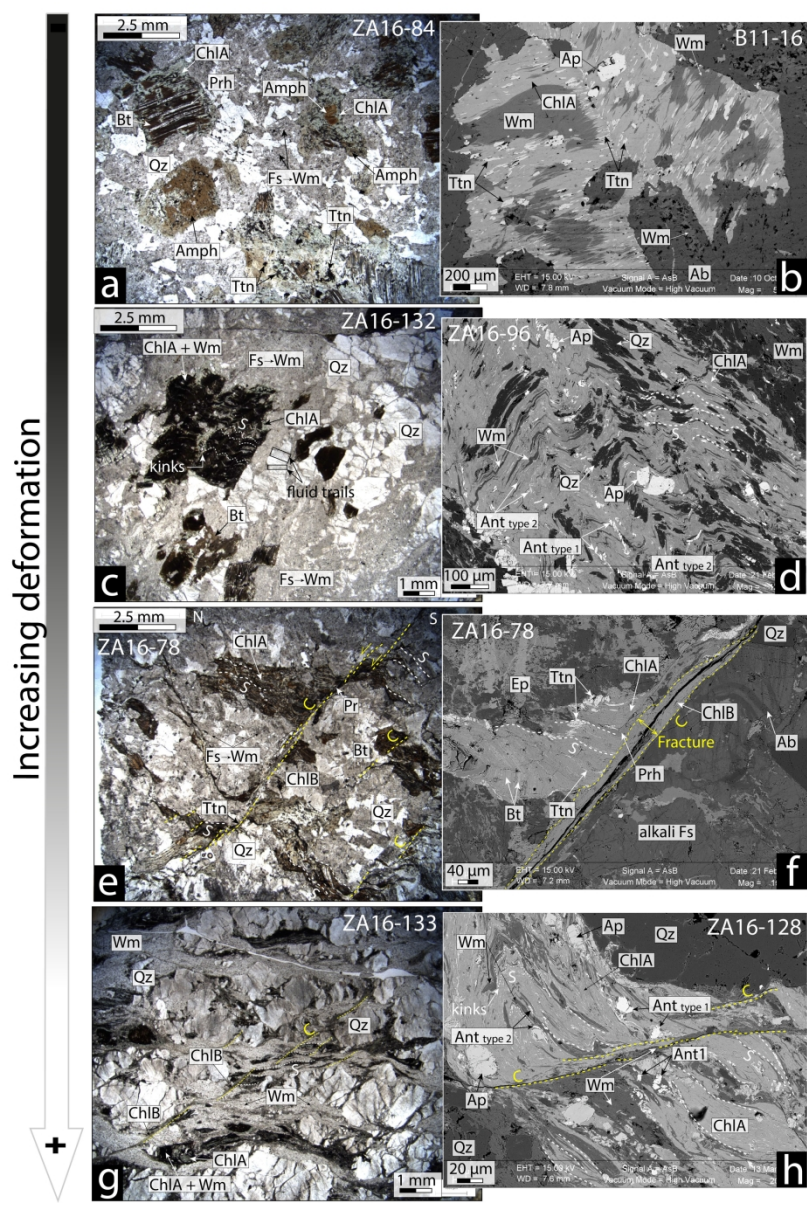


Figure 4. Microphotographs (optical microscope and SEM) of differently deformed granodioritic samples  
204x305mm (300 x 300 DPI)

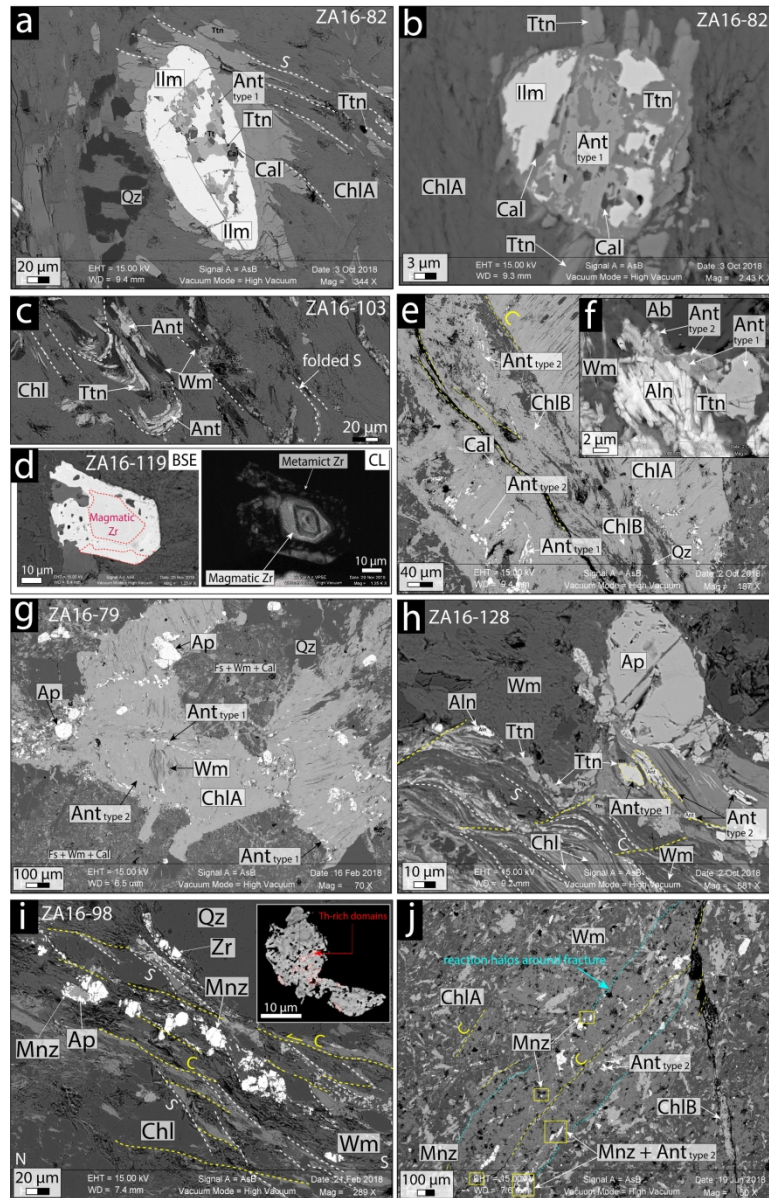


Figure 5. SEM images of accessory minerals in the granodiorite

187x292mm (300 x 300 DPI)

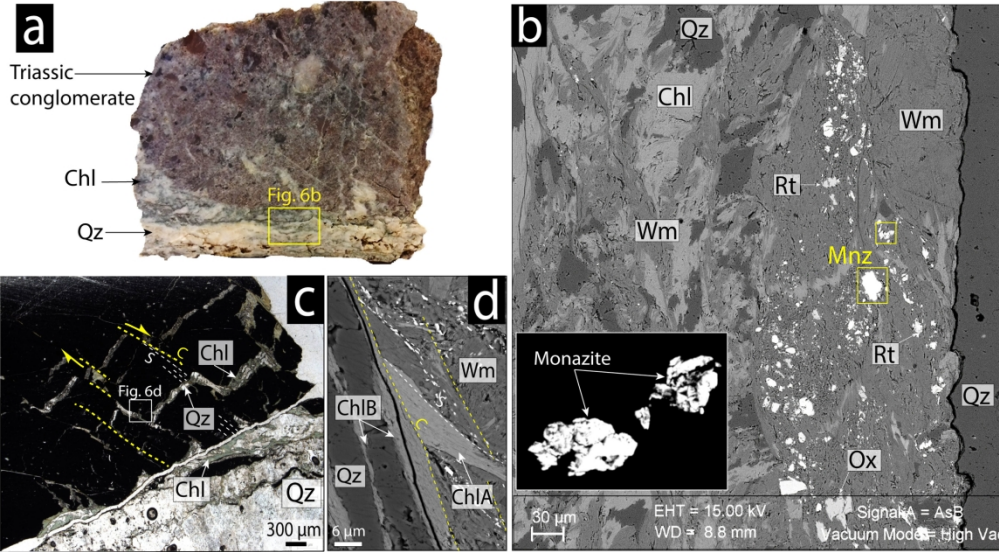


Figure 6. Microviews of Triassic sediments

197x110mm (300 x 300 DPI)



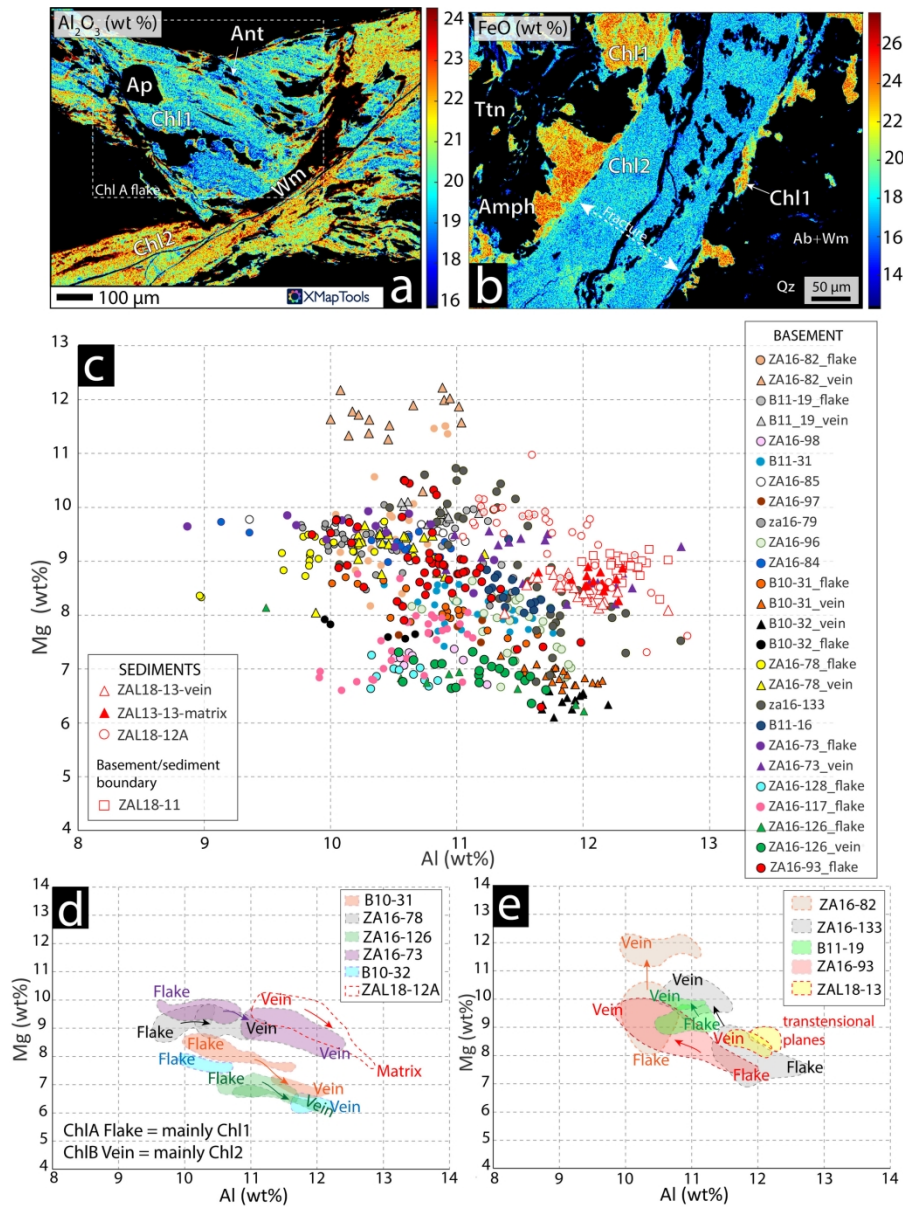


Figure 7. Chlorite chemical composition

189x254mm (300 x 300 DPI)



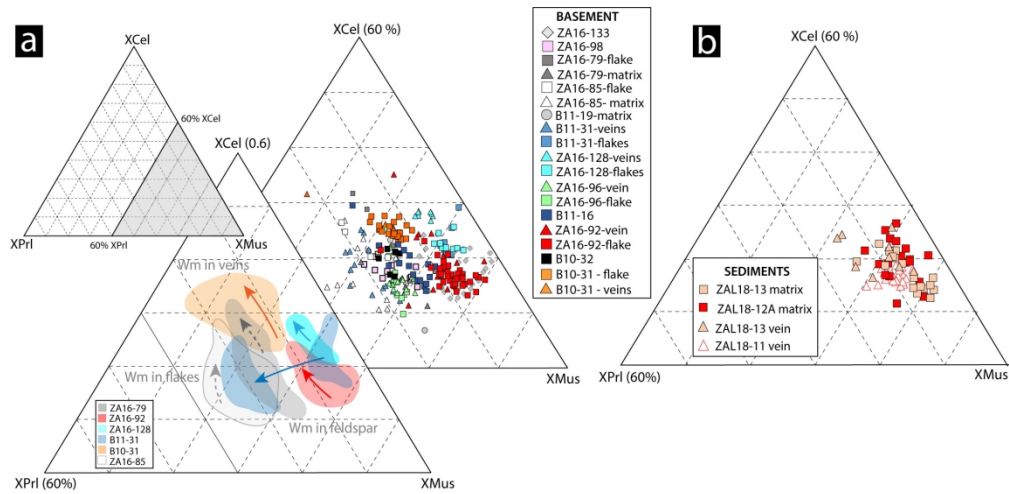


Figure 8. White mica chemical composition  
190x92mm (300 x 300 DPI)

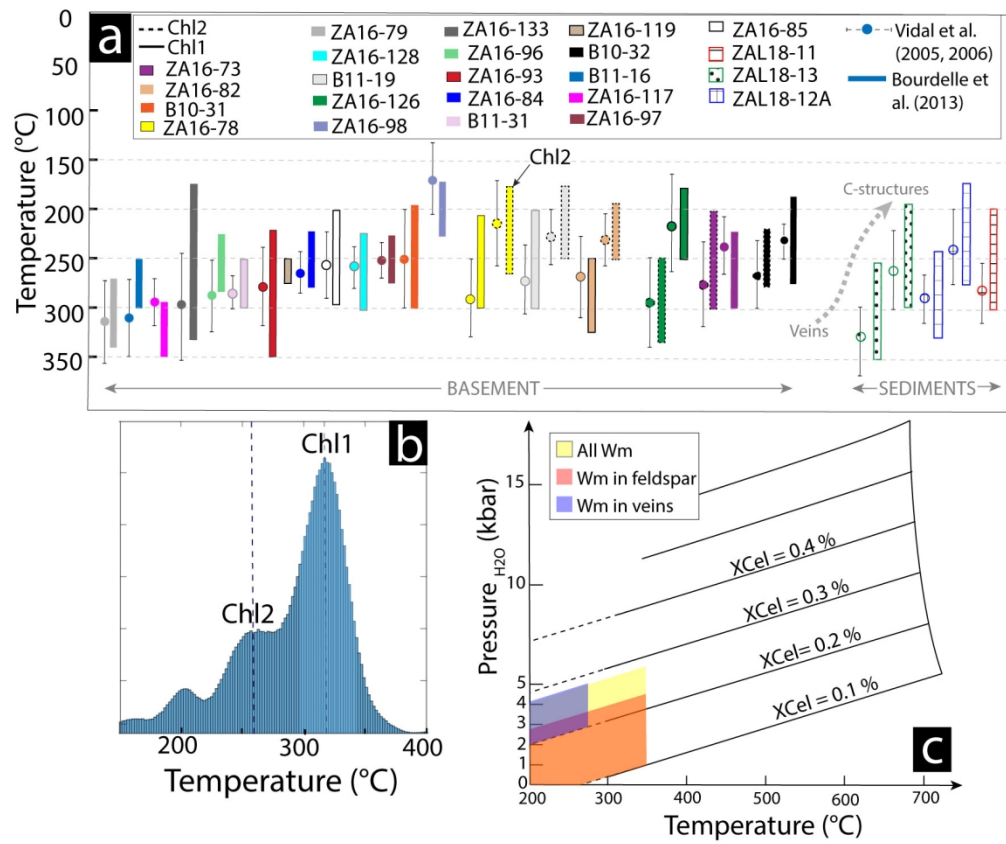


Figure 9. Thermobarometry

149x125mm (300 x 300 DPI)

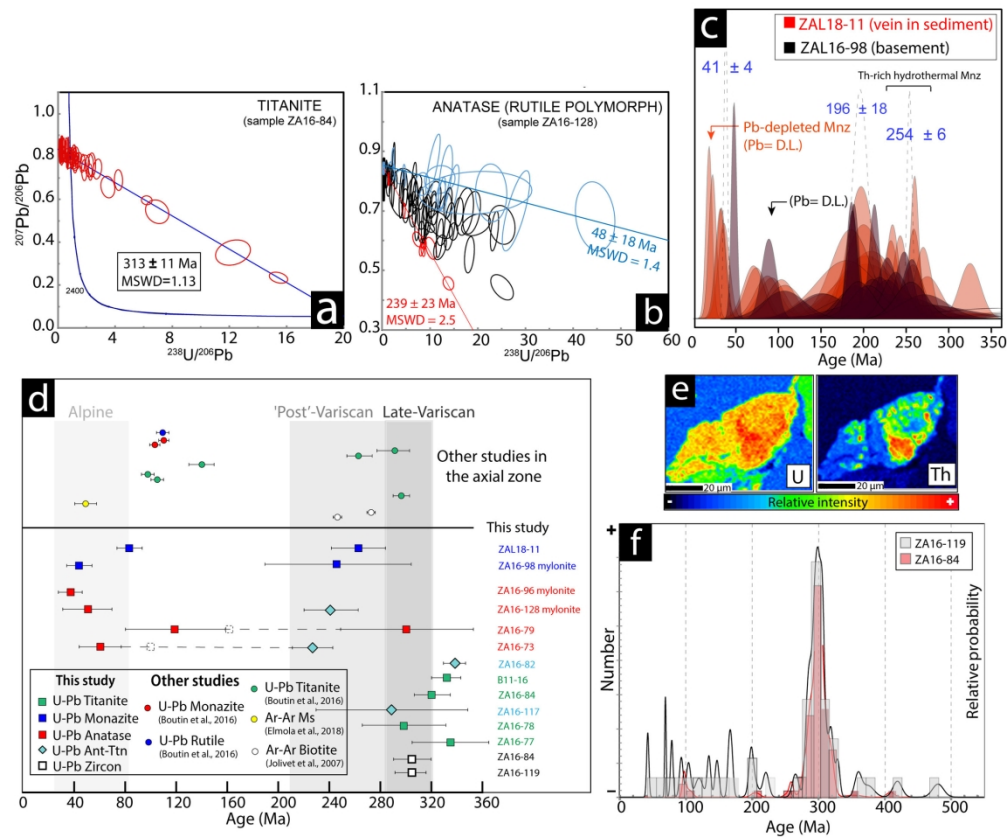
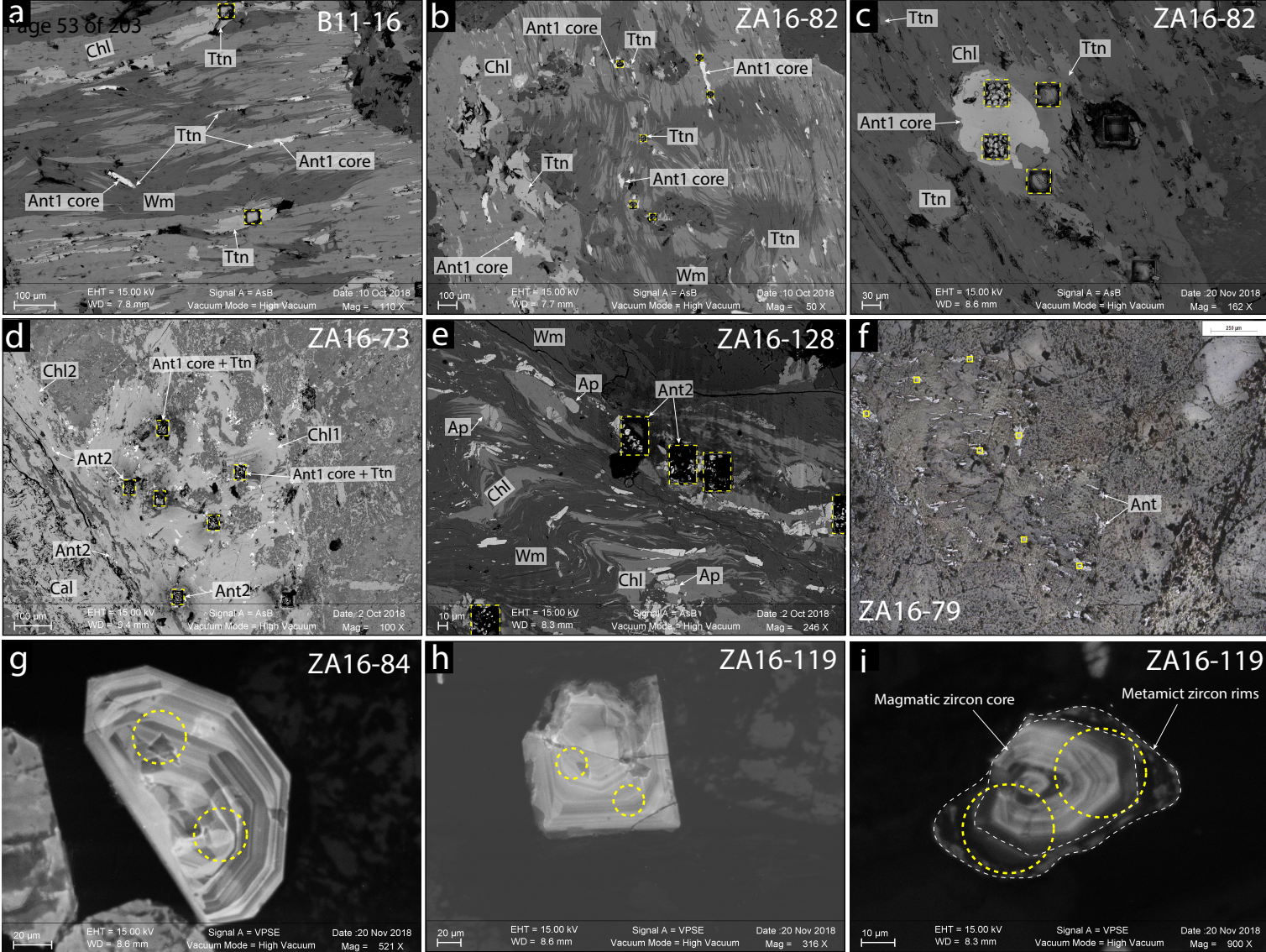


Figure 10. Geochronological results

189x166mm (300 x 300 DPI)

| Sample   | Deformation                        | Ttn age (Ma)         | Ant age (Ma)         | Mnz age (Ma)     | Zr age (Ma)             | Comments                                                  |
|----------|------------------------------------|----------------------|----------------------|------------------|-------------------------|-----------------------------------------------------------|
| B11-16   | undeformed                         | 336 ± 12             |                      |                  |                         |                                                           |
| ZA16-119 | undeformed                         |                      |                      |                  | 310 ± 20<br>285-291 (?) | Metamict zircon domains                                   |
| ZA16-117 | undeformed                         | 337 ± 20<br>293 ± 59 |                      |                  |                         | Relicts of anatase in titanite                            |
| ZA16-84  | undeformed                         | 313 ± 11             |                      |                  | 300 ± 10                |                                                           |
| ZA16-77  | little deformed                    | 337 ± 34             |                      |                  |                         |                                                           |
| ZA16-79  | distributed to discretely deformed |                      | 301 ± 56<br>120 ± 39 |                  |                         | Difficult distinction between two anatase age populations |
| ZA16-82  | discretely deformed                | 339 ± 7              |                      |                  |                         | Relicts of anatase in titanite                            |
| ZA16-78  | discretely deformed                | 303 ± 36             |                      |                  |                         | Titanite only                                             |
| ZA16-73  | discretely deformed                |                      | 221 ± 19<br>60 ± 18  |                  |                         |                                                           |
| ZA16-128 | discretely deformed to mylonite    |                      | 239 ± 23<br>48 ± 18  |                  |                         |                                                           |
| ZA16-96  | mylonite                           |                      | 39 ± 8               |                  |                         | Low variability of initial Pb                             |
| ZA16-98  | (proto-)mylonite                   |                      |                      | 254 ± 6<br>< 50  |                         | Ages < 100 Ma for Pb < D.L.<br>Ages < 50 Ma for Mnz-Thr   |
| ZA16-11  | Triassic sediment                  |                      |                      | 196 ± 18<br>< 20 |                         | Ages < 20 Ma for Pb < D.L.                                |

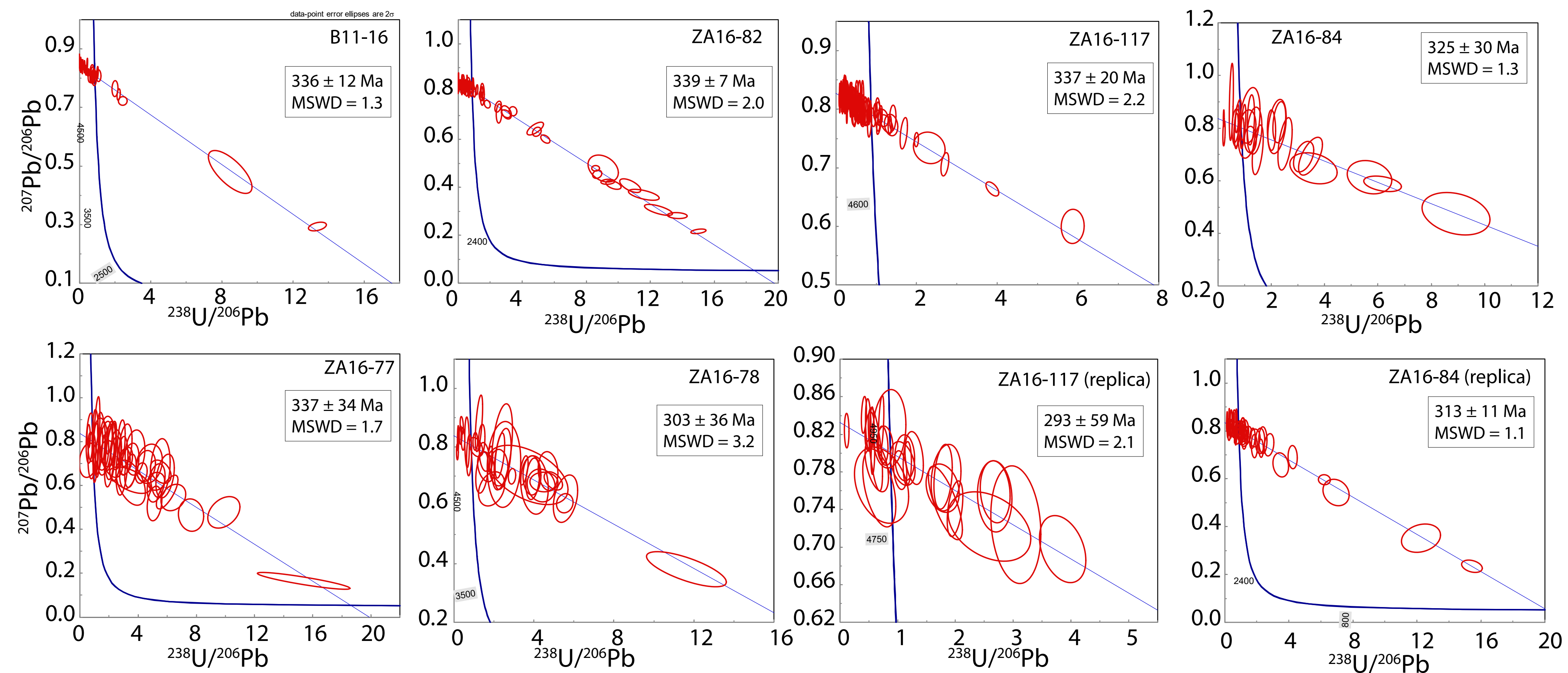
**Table 1** Summary of sample characteristic and ages.



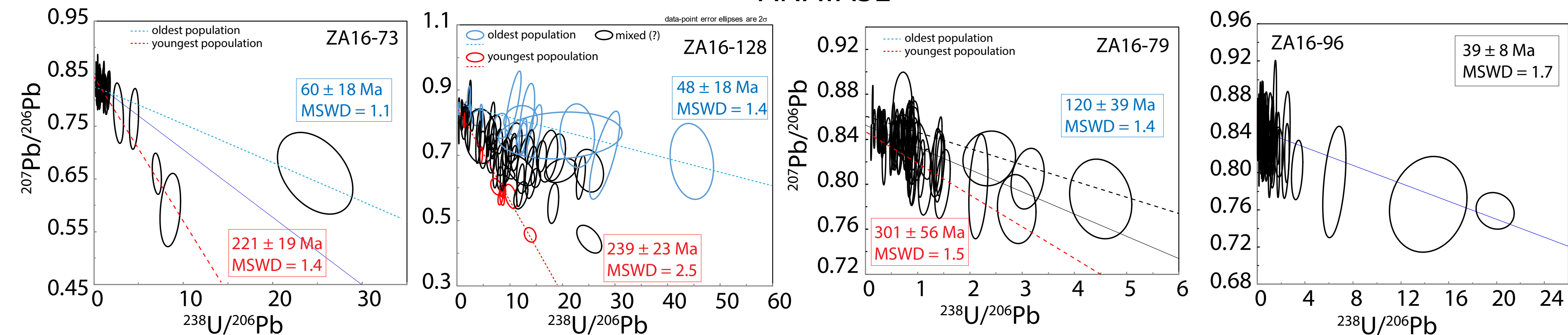
**Figure S1.** Examples of the location of the laser spots for dating on BSE images (a-e, g-i) and under reflected light (f). Laser spot location is indicated by the yellow dashed square (anatase and titanite) or circle (zircon).



## TITANITE



## ANATASE



## ZIRCON

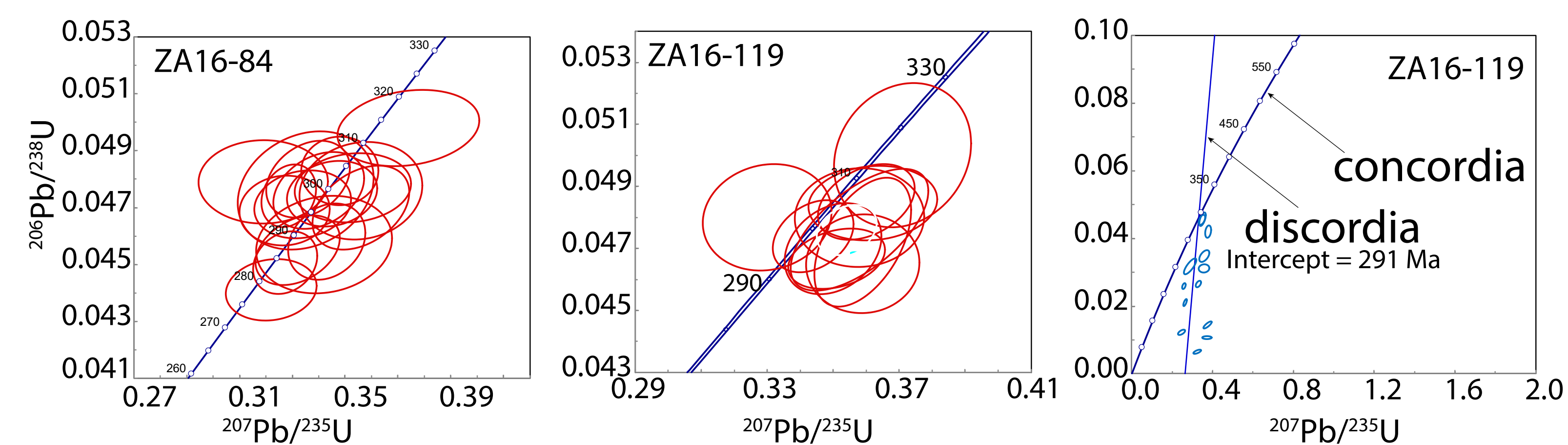


Fig. S1. Tera-Wasserburg diagrams for dated titanite and anatase, concordia diagrams for zircon.

## **Appendix S1. Analytical methods for geochronology and monazite analysis**

### **1. Protocol used for monazite EPMA compositional analysis**

Monazite was analyzed by electron probe micro-analysis (EPMA) with a JEOL JXA-8230 instrument at the Institute des Sciences de la Terre (ISTerre, Grenoble) on thin sections coated with a 55-60 nm thick layer of carbon to avoid material degradation during analysis at high beam current (Montel et al., 2011). Standards were coated in the same way. For the point analyses, the acceleration voltage was set at 15 keV with a spot beam size and a beam current of 200 nA. The duration of each analysis was ~9 minutes. During this exposure time, the evolution of the absorbed current was negligible ( $< 5$  nA).

Quantitative analyses were carried out using the X-ray lines:  $\text{SiK}\alpha$ ,  $\text{UM}\beta$ ,  $\text{ThM}\alpha$ ,  $\text{CaK}\alpha$ ,  $\text{PK}\alpha$ ,  $\text{YL}\alpha$ ,  $\text{DyL}\beta$ ,  $\text{GdL}\beta$ ,  $\text{SmL}\beta$ ,  $\text{PrL}\beta$ ,  $\text{NdL}\alpha$ ,  $\text{CeL}\alpha$ ,  $\text{LaL}\alpha$ ,  $\text{PbM}\beta$ . Background positions were carefully selected with high sensitivity wavelength scans before and after the element signal. The background value for each line was estimated by linear interpolation. A calibrated overlap correction of 0.0079 was applied for peak interference of  $\text{ThM}\alpha$  on  $\text{UM}\beta$ . A standard monazite (Madagascar, Paquette et al., 2007) was analyzed before and after the unknown analyses of the target (5 points each time) to track possible instrumental drift and to verify the consistency of the age calculated for the monazite grains. Other standards used were  $\text{ThO}_2$  for thorium,  $\text{UO}_2$  for uranium and crocoite ( $\text{PbCrO}_4$ ) for lead. ZAF correction procedure was applied using the JEOL software for quantitative analysis. EPMA X-rays maps of monazite grains was done for Si, U, Th, Ca using an acceleration voltage of 15kV, a beam current of 100 nA with a focused beam and a counting time per pixel of 500 ms.

U, Th and Pb contents were measured with counting time (peak plus background) of 480s for Pb, 300s for U and 160s for Th. The detection limit associated were 90 ppm for Pb, 120 ppm for U and 115 ppm for Th. For each monazite analysis, a chemical U-Th-Pb age was determined (Montel et al., 1996). Ages obtained for the standard monazite Madagascar cluster around 552



$\pm 4$  Ma. Monazite analyses in studied samples were divided into populations on the base of their composition (e.g. ThO<sub>2</sub> content, see the main text for details). The average age of each population was calculated using the software NiLeDAM (Seydoux-Guillaume et al., 2012).

## **2. U/Pb geochronology: titanite, rutile and zircon standards**

Titanite and anatase (rutile polymorph) were dated *in-situ* by the U-Pb LA-ICP-MS technique at Trinity College, Dublin (Ireland). U-Pb ages were determined using a Photon Machines Analyte Exite 193 nm ArF Excimer laser-ablation system with a Helex 2-volume ablation cell coupled to an Agilent 7900 ICPMS. The ICPMS was tuned using NIST 612 standard glass to yield Th/U ratios of unity and low oxide production rates (ThO<sup>+</sup>/Th<sup>+</sup> typically <0.15%). 0.15 l/min He carrier gas was fed into the cell body and 0.25 l/min He was fed into the cup. The aerosol was subsequently mixed with 0.6 l/min Ar make-up gas and a small volume of N<sub>2</sub> (ca. 10 ml/min) in a c. 1 cm<sup>3</sup> signal smoothing device to enhance signal sensitivity and reduce oxide formation. NIST612 was used as the trace element primary standard for titanite, rutile and zircon. For titanite analysis, OLT-1 (Kennedy et al., 2010) was used as the primary standard for titanite geochronology (published TIMS ages of  $1014.8 \pm 2$  Ma, obtained age of  $1018 \pm 5$  Ma) while MKED (Spandler et al., 2016) was used as a secondary age standard (TIMS age of  $1517.3 \pm 0.3$ , obtained age of  $1541 \pm 8$  Ma). The trace elements analysed were: <sup>90</sup>Zr, <sup>139</sup>La, <sup>51</sup>V, <sup>93</sup>Nb, <sup>43</sup>Ca, <sup>153</sup>Eu, <sup>157</sup>Gd, <sup>202</sup>Hg, <sup>204</sup>Pb, <sup>206</sup>Pb, <sup>207</sup>Pb, <sup>208</sup>Pb, <sup>232</sup>Th, <sup>238</sup>U, <sup>172</sup>Yb, <sup>147</sup>Sm, <sup>181</sup>Ta. For analysis of rutile polymorphs, rutile R10 (Luvizotto et al., 2009) was used as the primary standard (U-Pb TIMS age of 1090 Ma, obtained age of  $1089 \pm 5$  Ma). Rutile R19 (TIMS age of  $489.5 \pm 0.9$  Ma, obtained age of  $491 \pm 11$ ) and PCA-S207 rutile (age of  $1865.0 \pm 7.5$  Ma, obtained age of  $1921 \pm 36$ ) was used as secondary standards (Zack et al., 2011; Bracciali et al., 2013). The trace elements analyzed were Al, <sup>43</sup>Ca, <sup>49</sup>Ti, <sup>24</sup>Mg, <sup>51</sup>V, <sup>52</sup>Cr, <sup>57</sup>Fe, <sup>89</sup>Y, <sup>90</sup>Zr, <sup>93</sup>Nb, <sup>118</sup>Sn, <sup>121</sup>Sb, <sup>181</sup>Ta, <sup>182</sup>W, <sup>202</sup>Hg, <sup>204</sup>Pb, <sup>206</sup>Pb, <sup>207</sup>Pb, <sup>208</sup>Pb, <sup>232</sup>Th and <sup>238</sup>U. For zircon analysis

the primary standard employed was zircon 91500. The zircon age standards WRS1348 (TIMS age of  $526.26 \pm 0.70$ , obtained age of  $523.4 \pm 2.1$  Ma), Plesovice and Temora-2 (TIMS age of  $416.8 \pm 1.3$ , obtained age of  $416.5 \pm 2.6$  Ma) were used as secondary age standards (Chew et al, 2019 and references therein). The trace elements analysed were:  $^{49}\text{Ti}$ ,  $^{90}\text{Zr}$ ,  $^{202}\text{Hg}$ ,  $^{204}\text{Pb}$ ,  $^{206}\text{Pb}$ ,  $^{207}\text{Pb}$ ,  $^{208}\text{Pb}$ ,  $^{232}\text{Th}$  and  $^{238}\text{U}$ . Three of each standard were analysed under the same conditions as the unknowns, with each block of unknowns comprising 20-30 analyses.

The raw titanite and rutile isotope data were reduced using the “VizualAge UcomPbine” data reduction scheme (DRS) of Chew et al. (2014), a modification of the U-Pb geochronology “VizualAge” DRS of Petrus & Kamber (2012) that can account for the presence of variable common Pb in the primary standard materials. The “VizualAge” DRS was employed for zircon data reduction. Both DRSs runs within the freeware IOLITE package of Paton et al. (2011). In IOLITE, user-defined time intervals are established for the baseline correction procedure to calculate session-wide baseline-corrected values for each isotope. The time-resolved fractionation response of individual standard analyses is then characterised using a user-specified down-hole correction model (such as an exponential curve, a linear fit or a smoothed cubic spline). The VizualAge data reduction scheme then fits this appropriate session-wide “model” U-Th-Pb fractionation curve to the time-resolved standard data and the unknowns. Sample-standard bracketing is applied after the correction of down-hole fractionation to account for long-term drift in isotopic or elemental ratios by normalizing all ratios to those of the U-Pb reference standards. Common Pb in the titanite and rutile standards was corrected using the  $^{207}\text{Pb}$ -based correction method.

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- 119

| Sample                | ZA16-82                 |       | B11-19                  |       |       | ZA16-98                 |       |       | B11-31                  |       |       | ZA16-85                 |       |       | ZA16-97                 |  |
|-----------------------|-------------------------|-------|-------------------------|-------|-------|-------------------------|-------|-------|-------------------------|-------|-------|-------------------------|-------|-------|-------------------------|--|
| Lat/Long              | 42°40'7.3"N/0°16'43.3"E |       | 42°40'6.9"N/0°16'42.9"E |       |       | 42°40'2.3"N/0°16'31.3"E |       |       | 42°39'51.7"N/0°16'9.3"E |       |       | 42°40'6.1"N/0°16'40.6"E |       |       | 42°40'0.9"N/0°16'32.4"E |  |
| Deformation           | Discretely deformed     |       | Discretely deformed     |       |       | Mylonite                |       |       | Mylonite                |       |       | Distributed deformation |       |       | Mylonite                |  |
| Mineral               | Chl1                    | Chl2  | Chl1                    | Chl2  | Wm1   | Chl                     | Wm2   | Wm1   | Chl                     | Wm2   | Wm1   | Chl                     | Wm2   | Wm1   | Chl                     |  |
| <b>Oxides</b>         |                         |       |                         |       |       |                         |       |       |                         |       |       |                         |       |       |                         |  |
| SiO2                  | 27,60                   | 28,37 | 26,80                   | 27,74 | 47,62 | 25,65                   | 48,08 | 47,50 | 28,28                   | 48,70 | 47,43 | 27,41                   | 48,66 | 47,39 | 27,09                   |  |
| TiO2                  | 0,07                    | 0,05  | 0,09                    | 0,02  | 0,02  | 0,11                    | 0,17  | 0,02  | 0,17                    | 0,16  | 0,15  | 0,12                    | 0,06  | 0,20  | 0,02                    |  |
| Al2O3                 | 19,81                   | 20,57 | 19,82                   | 20,76 | 35,97 | 20,07                   | 32,35 | 32,42 | 21,25                   | 33,60 | 32,27 | 18,96                   | 34,52 | 32,82 | 20,80                   |  |
| FeO                   | 23,85                   | 17,85 | 24,46                   | 22,58 | 1,01  | 29,04                   | 2,27  | 0,93  | 22,08                   | 1,39  | 2,60  | 24,49                   | 1,30  | 2,46  | 27,96                   |  |
| MnO                   | 0,52                    | 0,43  | 0,32                    | 0,30  | 0,04  | 0,45                    | 0,06  | 0,01  | 0,33                    | 0,05  | <D.L. | 0,51                    | <D.L. | 0,04  | 0,34                    |  |
| MgO                   | 16,28                   | 20,26 | 15,27                   | 15,92 | 0,78  | 12,10                   | 1,58  | 1,11  | 13,70                   | 1,28  | 1,40  | 15,98                   | 1,15  | 1,92  | 12,90                   |  |
| CaO                   | 0,09                    | 0,10  | 0,09                    | 0,11  | 0,06  | 0,07                    | 0,09  | 0,07  | 0,13                    | 0,04  | 0,05  | 0,05                    | 0,08  | 0,08  | 0,04                    |  |
| Na2O                  | 0,07                    | 0,02  | 0,05                    | <D.L. | 0,19  | 0,01                    | 0,16  | 0,32  | 0,04                    | 0,16  | 0,24  | 0,02                    | 0,41  | 0,42  | 0,03                    |  |
| K2O                   | 0,08                    | 0,02  | 0,03                    | 0,01  | 9,31  | 0,06                    | 8,75  | 9,30  | 1,03                    | 9,17  | 10,32 | 0,03                    | 8,35  | 8,96  | 0,02                    |  |
| Total                 | 88,38                   | 87,67 | 86,93                   | 87,44 | 95,02 | 87,56                   | 93,52 | 91,68 | 87,03                   | 94,55 | 94,47 | 87,64                   | 94,52 | 94,30 | 89,21                   |  |
| <b>Cations</b>        |                         |       |                         |       |       |                         |       |       |                         |       |       |                         |       |       |                         |  |
| Si                    | 2,81                    | 2,82  | 2,83                    | 2,87  | 3,13  | 2,72                    | 3,23  | 3,24  | 2,89                    | 3,22  | 3,20  | 2,83                    | 3,20  | 3,17  | 2,79                    |  |
| Ti                    | 0,01                    | 0,03  | 0,01                    | 0,00  | <D.L. | 0,01                    | 0,01  | 0,00  | 0,01                    | 0,01  | 0,01  | 0,01                    | 0,00  | 0,01  | 0,00                    |  |
| Al                    | 2,38                    | 2,33  | 2,47                    | 2,53  | 2,79  | 2,51                    | 2,56  | 2,61  | 2,56                    | 2,62  | 2,56  | 2,31                    | 2,68  | 2,59  | 2,52                    |  |
| FeTOT                 | 1,97                    | 1,52  | 2,16                    | 1,96  | 0,06  | 2,51                    | 0,13  | 0,05  | 1,81                    | 0,08  | 0,15  | 2,05                    | 0,07  | 0,14  | 2,35                    |  |
| Mn                    | 0,05                    | 0,03  | 0,03                    | 0,03  | 0,00  | 0,04                    | 0,00  | 0,00  | 0,03                    | 0,00  | 0,00  | 0,04                    | 0,00  | 0,00  | 0,03                    |  |
| Mg                    | 2,47                    | 2,85  | 2,41                    | 2,46  | 0,08  | 1,91                    | 0,16  | 0,11  | 2,09                    | 0,13  | 0,14  | 2,46                    | 0,11  | 0,19  | 1,98                    |  |
| Ca                    | 0,01                    | 0,04  | 0,01                    | 0,01  | 0,00  | 0,01                    | 0,01  | 0,00  | 0,01                    | 0,00  | 0,00  | 0,01                    | 0,01  | 0,01  | 0,00                    |  |
| Na                    | 0,01                    | 0,01  | 0,01                    | 0,00  | 0,02  | 0,00                    | 0,02  | 0,04  | 0,01                    | 0,02  | 0,03  | 0,00                    | 0,05  | 0,06  | 0,01                    |  |
| K                     | 0,01                    | 0,00  | 0,00                    | 0,00  | 0,78  | 0,01                    | 0,75  | 0,81  | 0,13                    | 0,77  | 0,89  | 0,00                    | 0,70  | 0,77  | 0,00                    |  |
| Oxygens               | 14                      | 14    | 14                      | 14    | 11    | 14                      | 11    | 11    | 14                      | 11    | 11    | 14                      | 11    | 11    | 14                      |  |
| <i>XMg</i>            | 0,63                    | 0,78  | 0,62                    | 0,65  | 0,58  | 0,50                    | 0,55  | 0,68  | 0,65                    | 0,62  | 0,49  | 0,62                    | 0,61  | 0,58  | 0,52                    |  |
| <i>AlVI</i>           | 1,20                    | 1,18  | 1,31                    | 1,41  | -     | 1,24                    | -     | -     | 1,46                    | -     | -     | 1,15                    | -     | -     | 1,31                    |  |
| <i>Octahedral sum</i> | 5,69                    | 5,58  | 5,81                    | 5,76  | -     | 5,71                    | -     | -     | 5,39                    | -     | -     | 5,71                    | -     | -     | 5,67                    |  |
| <i>Xceladonite</i>    | -                       | -     | -                       | -     | 0,07  | -                       | 0,17  | 0,14  | -                       | 0,14  | 0,21  | -                       | 0,10  | 0,19  | -                       |  |
| <i>Xmuscovite</i>     | -                       | -     | -                       | -     | 0,74  | -                       | 0,62  | 0,68  | -                       | 0,67  | 0,69  | -                       | 0,64  | 0,62  | -                       |  |
| <i>Xpyrophyllite</i>  | -                       | -     | -                       | -     | 0,17  | -                       | 0,18  | 0,14  | -                       | 0,18  | 0,07  | -                       | 0,21  | 0,14  | -                       |  |

Chl1 flake

Chl2 veins

| Sample         | ZA16-84                 | ZA16-96                  |       |       | ZA16-79                  |       |       | B10-31                  |       |       | B10-32                  |       |       | ZA16-78                 |       |
|----------------|-------------------------|--------------------------|-------|-------|--------------------------|-------|-------|-------------------------|-------|-------|-------------------------|-------|-------|-------------------------|-------|
| Lat/Long       | 42°40'7.3"N/0°16'43.3"E | 42°39'59.1"N/0°16'35.1"E |       |       | 42°39'58.9"N/0°17'8.95"E |       |       | 42°39'49.2"N/0°17'4.4"E |       |       | 42°39'46.3"N/0°17'2.0"E |       |       | 42°39'59.4"N/0°17'8.5"E |       |
| Deformation    | Undeformed              | Mylonite                 |       |       | Distributed deformation  |       |       | Mylonite                |       |       | Mylonite                |       |       | Discretely deformed     |       |
| Mineral        | Chl                     | Chl                      | Wm1   | Wm2   | Chl1                     | Wm1   | Wm2   | Chl1                    | Chl2  | Wm    | Chl1                    | Chl2  | Wm    | Chl1                    | Chl2  |
| <i>Oxides</i>  |                         |                          |       |       |                          |       |       |                         |       |       |                         |       |       |                         |       |
| SiO2           | 29,59                   | 27,14                    | 48,35 | 49,23 | 26,72                    | 44,97 | 47,78 | 27,37                   | 26,78 | 49,30 | 27,64                   | 26,72 | 49,67 | 28,60                   | 27,42 |
| TiO2           | 1,56                    | <D.L.                    | 0,10  | 0,22  | 0,21                     | 0,11  | 0,14  | 0,24                    | 0,01  | 0,06  | 0,02                    | 0,02  | 0,04  | 0,69                    | 0,03  |
| Al2O3          | 17,68                   | 21,02                    | 33,96 | 32,92 | 18,81                    | 34,68 | 33,46 | 19,12                   | 22,67 | 31,82 | 18,81                   | 22,51 | 32,45 | 18,58                   | 20,61 |
| FeO            | 22,98                   | 24,78                    | 1,78  | 1,04  | 23,93                    | 2,79  | 1,34  | 26,67                   | 28,07 | 3,43  | 29,36                   | 29,05 | 2,19  | 23,99                   | 24,34 |
| MnO            | 0,32                    | 0,90                     | 0,03  | 0,04  | 0,31                     | 0,04  | 0,00  | 0,42                    | 0,53  | 0,02  | 0,21                    | 0,18  | <D.L. | 0,35                    | 0,51  |
| MgO            | 15,79                   | 14,30                    | 1,20  | 1,37  | 15,97                    | 1,76  | 1,43  | 14,42                   | 10,86 | 2,64  | 13,12                   | 10,36 | 1,63  | 14,93                   | 14,44 |
| CaO            | 0,53                    | 0,04                     | 0,03  | <D.L. | 0,04                     | 0,07  | 0,10  | 0,03                    | 0,05  | 0,03  | 0,03                    | 0,05  | 0,07  | 0,15                    | 0,11  |
| Na2O           | <D.L.                   | 0,02                     | 0,09  | 0,11  | 0,04                     | 0,68  | 0,26  | <D.L.                   | 0,02  | 0,05  | 0,01                    | 0,02  | 0,15  | 0,05                    | 0,04  |
| K2O            | 0,33                    | 0,03                     | 9,25  | 9,35  | 0,02                     | 9,37  | 9,16  | 0,02                    | 0,10  | 9,66  | 0,06                    | 0,03  | 9,85  | 1,12                    | 0,06  |
| Total          | 88,86                   | 88,23                    | 94,78 | 94,32 | 86,09                    | 94,48 | 93,67 | 88,30                   | 89,10 | 97,01 | 89,28                   | 88,92 | 96,04 | 88,46                   | 87,55 |
| <i>Cations</i> |                         |                          |       |       |                          |       |       |                         |       |       |                         |       |       |                         |       |
| Si             | 2,98                    | 2,80                     | 3,20  | 3,26  | 2,81                     | 3,03  | 3,20  | 2,83                    | 2,77  | 3,23  | 2,88                    | 2,75  | 3,26  | 2,91                    | 2,83  |
| Ti             | 0,12                    | 0,00                     | 0,00  | 0,01  | 0,02                     | 0,01  | 0,01  | 0,02                    | 0,00  | 0,00  | 0,00                    | 0,00  | 0,00  | 0,05                    | 0,00  |
| Al             | 2,10                    | 2,55                     | 2,65  | 2,57  | 2,33                     | 2,76  | 2,64  | 2,33                    | 2,77  | 2,46  | 2,31                    | 2,73  | 2,51  | 2,23                    | 2,42  |
| FeTOT          | 1,87                    | 2,09                     | 0,10  | 0,06  | 2,04                     | 0,16  | 0,08  | 2,24                    | 2,40  | 0,19  | 2,52                    | 2,41  | 0,12  | 1,96                    | 1,92  |
| Mn             | 0,03                    | 0,08                     | 0,00  | 0,00  | 0,03                     | 0,00  | 0,00  | 0,04                    | 0,05  | 0,00  | 0,02                    | 0,02  | 0,00  | 0,03                    | 0,04  |
| Mg             | 2,37                    | 2,20                     | 0,12  | 0,14  | 2,50                     | 0,18  | 0,14  | 2,22                    | 1,68  | 0,26  | 2,04                    | 1,59  | 0,16  | 2,27                    | 2,39  |
| Ca             | 0,06                    | 0,00                     | 0,00  | 0,00  | 0,00                     | 0,00  | 0,01  | 0,00                    | 0,01  | 0,00  | 0,00                    | 0,01  | 0,00  | 0,02                    | 0,01  |
| Na             | 0,00                    | 0,00                     | 0,01  | 0,01  | 0,01                     | 0,09  | 0,03  | -0,01                   | 0,00  | 0,01  | 0,00                    | 0,00  | 0,02  | 0,01                    | 0,00  |
| K              | 0,04                    | 0,00                     | 0,78  | 0,79  | 0,00                     | 0,81  | 0,78  | 0,00                    | 0,01  | 0,81  | 0,01                    | 0,00  | 0,82  | 0,15                    | 0,00  |
| Oxygens        | 14                      | 14                       | 11    | 11    | 14                       | 11    | 11    | 14                      | 14    | 11    | 14                      | 14    | 11    | 14                      | 14    |
| XMg            | 0,65                    | 0,56                     | 0,55  | 0,70  | 0,63                     | 0,53  | 0,66  | 0,58                    | 0,45  | 0,58  | 0,48                    | 0,49  | 0,57  | 0,65                    | 0,67  |
| AlVI           | 1,20                    | 1,35                     | -     | -     | 1,15                     | -     | -     | 1,18                    | 1,54  | -     | 1,20                    | 1,47  | -     | 1,20                    | 1,24  |
| Octahedral sum | 5,47                    | 5,72                     | -     | -     | 5,72                     | -     | -     | 5,67                    | 5,66  | -     | 5,78                    | 5,49  | -     | 5,46                    | 5,59  |
| Xceladonite    | -                       | -                        | 0,13  | 0,15  | -                        | 0,16  | 0,14  | -                       | -     | 0,25  | -                       | -     | 0,20  | -                       | -     |
| Xmuscovite     | -                       | -                        | 0,68  | 0,66  | -                        | 0,69  | 0,67  | -                       | -     | 0,60  | -                       | -     | 0,64  | -                       | -     |
| Xpyrophyllite  | -                       | -                        | 0,18  | 0,18  | -                        | 0,08  | 0,16  | -                       | -     | 0,14  | -                       | -     | 0,14  | -                       | -     |



| Sample                  | ZA16-133                             |       |       | B11-16                                |       | ZA16-73                                        |       | ZA16-128                             |       |       | ZA16-117                              |       | ZA16-126                             |  |
|-------------------------|--------------------------------------|-------|-------|---------------------------------------|-------|------------------------------------------------|-------|--------------------------------------|-------|-------|---------------------------------------|-------|--------------------------------------|--|
| Lat/Long<br>Deformation | 42°39'49.5"N/0°16'17.8"E<br>Mylonite |       |       | 42°40'7.9"N/0°16'47.9"E<br>Undeformed |       | 42°39'56.2"N/0°17'6.9"E<br>Discretely deformed |       | 42°39'49.2"N/0°16'16.6"E<br>Mylonite |       |       | 42°39'45.0"N/0°16'5.7"E<br>Undeformed |       | 42°39'48.9"N/0°16'17.5"E<br>Mylonite |  |
| Mineral                 | Chl1                                 | Chl2  | Wm    | Chl                                   | Wm    | Chl1                                           | Chl2  | Chl                                  | Wm1   | Wm2   | Chl                                   | Chl1  | Chl2                                 |  |
| <i>Oxides</i>           |                                      |       |       |                                       |       |                                                |       |                                      |       |       |                                       |       |                                      |  |
| SiO2                    | 26,33                                | 27,03 | 48,67 | 26,45                                 | 49,43 | 28,33                                          | 26,92 | 26,51                                | 48,97 | 48,58 | 26,33                                 | 26,02 | 28,67                                |  |
| TiO2                    | 0,05                                 | 0,19  | 0,35  | 0,06                                  | 0,20  | 1,47                                           | 0,01  | 0,29                                 | 0,12  | 0,20  | 0,01                                  | <D.L. | 0,04                                 |  |
| Al2O3                   | 23,11                                | 21,38 | 34,85 | 21,56                                 | 34,30 | 18,38                                          | 22,10 | 19,84                                | 32,57 | 31,07 | 19,80                                 | 21,20 | 23,86                                |  |
| FeO                     | 26,22                                | 22,15 | 2,41  | 23,85                                 | 0,84  | 23,74                                          | 22,90 | 29,63                                | 2,04  | 2,93  | 30,71                                 | 29,50 | 25,93                                |  |
| MnO                     | 0,15                                 | 0,12  | <D.L. | 0,38                                  | 0,03  | 0,24                                           | 0,24  | 0,43                                 | 0,05  | 0,02  | 0,70                                  | 0,42  | 0,31                                 |  |
| MgO                     | 13,17                                | 17,05 | 1,07  | 15,59                                 | 1,13  | 16,03                                          | 15,58 | 11,60                                | 1,61  | 2,04  | 11,87                                 | 11,88 | 8,86                                 |  |
| CaO                     | 0,04                                 | 0,10  | 0,03  | 0,08                                  | 0,07  | 0,18                                           | 0,09  | 0,06                                 | 0,08  | 0,11  | 0,06                                  | 0,07  | 0,11                                 |  |
| Na2O                    | 0,05                                 | 0,07  | 0,22  | <D.L.                                 | 0,14  | 0,01                                           | 0,01  | <D.L.                                | 0,13  | 0,12  | 0,03                                  | 0,02  | 0,03                                 |  |
| K2O                     | 0,02                                 | 0,04  | 10,55 | <D.L.                                 | 10,07 | 0,23                                           | <D.L. | 0,11                                 | 10,73 | 10,75 | 0,04                                  | <D.L. | 1,80                                 |  |
| Total                   | 89,15                                | 88,13 | 98,18 | 88,00                                 | 96,22 | 88,66                                          | 87,85 | 88,50                                | 96,29 | 95,85 | 89,54                                 | 89,12 | 89,63                                |  |
| <i>Cations</i>          |                                      |       |       |                                       |       |                                                |       |                                      |       |       |                                       |       |                                      |  |
| Si                      | 2,68                                 | 2,58  | 3,15  | 2,75                                  | 3,22  | 2,92                                           | 2,78  | 2,83                                 | 3,23  | 3,24  | 2,80                                  | 2,75  | 2,95                                 |  |
| Ti                      | 0,00                                 | 0,03  | 0,02  | 0,00                                  | 0,01  | 0,11                                           | 0,00  | 0,02                                 | 0,01  | 0,01  | 0,00                                  | 0,00  | 0,00                                 |  |
| Al                      | 2,63                                 | 2,51  | 2,66  | 2,64                                  | 2,63  | 2,24                                           | 2,69  | 2,50                                 | 2,53  | 2,44  | 2,48                                  | 2,64  | 2,90                                 |  |
| FeTOT                   | 1,93                                 | 2,06  | 0,13  | 2,07                                  | 0,05  | 2,05                                           | 1,98  | 2,65                                 | 0,11  | 0,16  | 2,73                                  | 2,61  | 2,23                                 |  |
| Mn                      | 0,01                                 | 0,01  | 0,00  | 0,03                                  | 0,00  | 0,02                                           | 0,02  | 0,04                                 | 0,00  | 0,00  | 0,06                                  | 0,04  | 0,03                                 |  |
| Mg                      | 2,57                                 | 2,53  | 0,10  | 2,42                                  | 0,11  | 2,47                                           | 2,40  | 1,85                                 | 0,16  | 0,20  | 1,88                                  | 1,87  | 1,36                                 |  |
| Ca                      | 0,01                                 | 0,01  | 0,00  | 0,01                                  | 0,01  | 0,02                                           | 0,01  | 0,01                                 | 0,01  | 0,01  | 0,01                                  | 0,01  | 0,01                                 |  |
| Na                      | 0,00                                 | 0,00  | 0,03  | 0,00                                  | 0,02  | 0,00                                           | 0,00  | 0,00                                 | 0,02  | 0,01  | 0,01                                  | 0,00  | 0,01                                 |  |
| K                       | 0,00                                 | 0,01  | 0,87  | 0,00                                  | 0,84  | 0,03                                           | 0,00  | 0,01                                 | 0,90  | 0,91  | 0,01                                  | 0,00  | 0,24                                 |  |
| Oxygens                 | 14                                   | 14    | 11    | 14                                    | 11    | 14                                             | 14    | 14                                   | 11    | 11    | 14                                    | 14    | 14                                   |  |
| XMg                     | 0,62                                 | 0,66  | 0,44  | 0,54                                  | 0,70  | 0,55                                           | 0,55  | 0,41                                 | 0,58  | 0,55  | 0,41                                  | 0,42  | 0,38                                 |  |
| AlVI                    | 1,31                                 | 1,13  | -     | 1,40                                  | -     | 1,27                                           | 1,47  | 1,35                                 | -     | -     | 1,28                                  | 1,40  | 1,85                                 |  |
| Octahedral sum          | 5,82                                 | 5,73  | -     | 5,92                                  | -     | 5,80                                           | 5,87  | 5,88                                 | -     | -     | 5,95                                  | 5,92  | 5,47                                 |  |
| Xceladonite             | -                                    | -     | 0,17  | -                                     | 0,14  | -                                              | -     | -                                    | 0,22  | 0,28  | -                                     | -     | -                                    |  |
| Xmuscovite              | -                                    | -     | 0,72  | -                                     | 0,72  | -                                              | -     | -                                    | 0,69  | 0,65  | -                                     | -     | -                                    |  |
| Xpyrophyllite           | -                                    | -     | 0,09  | -                                     | 0,13  | -                                              | -     | -                                    | 0,07  | 0,05  | -                                     | -     | -                                    |  |

| Sample                  | ZA16-119                               | ZA16-93                                            |             |             |             | ZAL18-11                                     |             | ZAL18-12                                      |             |             | ZAL18-13                                      |             |             |             |
|-------------------------|----------------------------------------|----------------------------------------------------|-------------|-------------|-------------|----------------------------------------------|-------------|-----------------------------------------------|-------------|-------------|-----------------------------------------------|-------------|-------------|-------------|
| Lat/Long<br>Deformation | 42°39'46.4"N/0°16'14.3"E<br>Undeformed | 42°40'1.1"N/0°16'38.4"E<br>Distributed deformation |             |             |             | 42°40'4.6"N/0°16'41.9"E<br>Vein in sediments |             | 42°40'1.3"N/0°16'43.4"E<br>Triassic sediments |             |             | 42°40'4.3"N/0°16'43.1"E<br>Triassic sediments |             |             |             |
| Mineral                 | Chl                                    | Chl1                                               | Chl2        | Wm1         | Wm2         | Chl2                                         | Wm          | Chl1                                          | Chl2        | Wm          | Chl1                                          | Chl2        | Wm1         | Wm2         |
| <b><i>Oxides</i></b>    |                                        |                                                    |             |             |             |                                              |             |                                               |             |             |                                               |             |             |             |
| SiO2                    | 27,68                                  | 27,84                                              | 25,18       | 48,72       | 48,62       | 27,83                                        | 48,68       | 27,27                                         | 28,82       | 47,37       | 26,17                                         | 27,49       | 47,23       | 49,25       |
| TiO2                    | 0,18                                   | 0,06                                               | 0,23        | 0,09        | 0,03        | <D.L.                                        | 0,05        | 0,09                                          | 0,01        | 0,32        | <D.L.                                         | 0,04        | 0,24        | 0,15        |
| Al2O3                   | 17,45                                  | 20,01                                              | 21,47       | 33,14       | 33,70       | 23,82                                        | 34,68       | 23,62                                         | 22,73       | 35,03       | 23,94                                         | 22,82       | 35,16       | 32,41       |
| FeO                     | 27,88                                  | 22,63                                              | 28,73       | 1,17        | 1,36        | 21,27                                        | 2,59        | 23,23                                         | 20,77       | 1,09        | 25,03                                         | 22,89       | 1,73        | 2,55        |
| MnO                     | 0,39                                   | 0,35                                               | 0,21        | <D.L.       | <D.L.       | 0,30                                         | <D.L.       | 0,30                                          | 0,21        | 0,04        | 0,27                                          | 0,19        | <D.L.       | 0,00        |
| MgO                     | 13,91                                  | 17,38                                              | 11,77       | 1,22        | 1,64        | 13,74                                        | 0,71        | 12,11                                         | 16,03       | 0,93        | 13,41                                         | 14,29       | 0,85        | 0,92        |
| CaO                     | 0,22                                   | 0,03                                               | <D.L.       | <D.L.       | <D.L.       | 0,04                                         | 0,03        | 0,05                                          | 0,12        | 0,13        | 0,01                                          | 0,05        | 0,04        | 0,08        |
| Na2O                    | 0,02                                   | <D.L.                                              | 0,02        | 0,11        | 0,21        | 0,03                                         | 0,40        | 0,04                                          | 0,02        | 1,17        | <D.L.                                         | 0,03        | 0,31        | 0,28        |
| K2O                     | 0,17                                   | <D.L.                                              | <D.L.       | 10,42       | 10,82       | 0,74                                         | 10,12       | 0,54                                          | 0,11        | 9,13        | 0,02                                          | 0,39        | 10,61       | 10,46       |
| Total                   | 87,90                                  | 88,32                                              | 87,61       | 94,88       | 96,38       | 87,79                                        | 97,26       | 87,29                                         | 88,83       | 95,25       | 88,87                                         | 88,21       | 96,20       | 96,12       |
| <b><i>Cations</i></b>   |                                        |                                                    |             |             |             |                                              |             |                                               |             |             |                                               |             |             |             |
| Si                      | 2,95                                   | 2,86                                               | 2,70        | 3,23        | 3,19        | 2,85                                         | 3,17        | 2,84                                          | 2,89        | 3,13        | 2,70                                          | 2,82        | 3,11        | 3,25        |
| Ti                      | 0,01                                   | 0,00                                               | 0,02        | 0,00        | 0,00        | 0,00                                         | 0,00        | 0,01                                          | 0,00        | 0,02        | 0,00                                          | 0,00        | 0,01        | 0,01        |
| Al                      | 2,20                                   | 2,42                                               | 2,72        | 2,59        | 2,61        | 2,87                                         | 2,66        | 2,90                                          | 2,69        | 2,73        | 2,91                                          | 2,76        | 2,73        | 2,52        |
| FeTOT                   | 2,49                                   | 1,94                                               | 2,58        | 0,06        | 0,07        | 1,82                                         | 0,14        | 2,02                                          | 1,74        | 0,06        | 2,16                                          | 1,97        | 0,10        | 0,14        |
| Mn                      | 0,04                                   | 0,03                                               | 0,02        | 0,00        | 0,00        | 0,03                                         | 0,00        | 0,03                                          | 0,02        | 0,00        | 0,02                                          | 0,02        | 0,00        | 0,00        |
| Mg                      | 2,21                                   | 2,66                                               | 1,88        | 0,12        | 0,16        | 2,10                                         | 0,07        | 1,88                                          | 2,40        | 0,09        | 2,06                                          | 2,19        | 0,08        | 0,09        |
| Ca                      | 0,03                                   | 0,00                                               | 0,00        | 0,00        | 0,00        | 0,00                                         | 0,00        | 0,01                                          | 0,01        | 0,01        | 0,00                                          | 0,01        | 0,00        | 0,01        |
| Na                      | 0,00                                   | 0,00                                               | 0,00        | 0,01        | 0,03        | 0,01                                         | 0,05        | 0,01                                          | 0,00        | 0,15        | -0,01                                         | 0,01        | 0,04        | 0,04        |
| K                       | 0,02                                   | 0,00                                               | 0,00        | 0,88        | 0,91        | 0,10                                         | 0,84        | 0,07                                          | 0,01        | 0,77        | 0,00                                          | 0,05        | 0,89        | 0,88        |
| Oxygens                 | 14                                     | 14                                                 | 14          | 11          | 11          | 14                                           | 11          | 14                                            | 14          | 11          | 14                                            | 14          | 11          | 11          |
| <i>XMg</i>              | <i>0,47</i>                            | <i>0,52</i>                                        | <i>0,42</i> | <i>0,65</i> | <i>0,68</i> | <i>0,54</i>                                  | <i>0,33</i> | <i>0,48</i>                                   | <i>0,58</i> | <i>0,60</i> | <i>0,49</i>                                   | <i>0,53</i> | <i>0,47</i> | <i>0,39</i> |
| <i>AlVI</i>             | <i>1,16</i>                            | <i>1,29</i>                                        | <i>1,44</i> | -           | -           | <i>1,74</i>                                  | -           | <i>1,74</i>                                   | <i>1,58</i> | -           | <i>1,61</i>                                   | <i>1,59</i> | -           | -           |
| <i>Octahedral sum</i>   | <i>5,90</i>                            | <i>5,92</i>                                        | <i>5,92</i> | -           | -           | <i>5,69</i>                                  | -           | <i>5,66</i>                                   | <i>5,74</i> | -           | <i>5,85</i>                                   | <i>5,76</i> | -           | -           |
| <i>Xceladonite</i>      | -                                      | -                                                  | -           | <i>0,17</i> | <i>0,19</i> | -                                            | <i>0,15</i> | -                                             | -           | <i>0,13</i> | -                                             | -           | <i>0,14</i> | <i>0,21</i> |
| <i>Xmuscovite</i>       | -                                      | -                                                  | -           | <i>0,72</i> | <i>0,73</i> | -                                            | <i>0,71</i> | -                                             | -           | <i>0,66</i> | -                                             | -           | <i>0,77</i> | <i>0,68</i> |
| <i>Xpyrophyllite</i>    | -                                      | -                                                  | -           | <i>0,10</i> | <i>0,06</i> | -                                            | <i>0,10</i> | -                                             | -           | <i>0,07</i> | -                                             | -           | <i>0,06</i> | <i>0,07</i> |

**Table S2.** Representative chemical composition of dated monazite for samples ZA16-98 and ZAL18-11.

| SESSION 1      |      |      |       |      |       |       |       |       |       |       |       |      |      |       |        |          |     |
|----------------|------|------|-------|------|-------|-------|-------|-------|-------|-------|-------|------|------|-------|--------|----------|-----|
| ZA16-98<br>No. | Wt%  |      |       |      |       |       |       |       |       |       |       |      |      |       |        |          |     |
| D.L. (ppm)     | CaO  | SiO2 | P2O5  | Y2O3 | Dy2O3 | Gd2O3 | Sm2O3 | Pr2O3 | Nd2O3 | Ce2O3 | La2O3 | ThO2 | UO2  | PbO   | TOTAL  | Age (Ma) | std |
| za16-98_Mz33   | 1,19 | 0,86 | 27,83 | 0,45 | 0,20  | 0,59  | 1,14  | 3,29  | 10,12 | 34,62 | 15,59 | 7,65 | 0,15 | 0,06  | 103,75 | 188      | 6   |
| za16-98_Mz34   | 1,15 | 0,70 | 28,49 | 0,43 | 0,15  | 0,63  | 1,23  | 3,30  | 10,36 | 33,83 | 16,06 | 7,38 | 0,16 | 0,07  | 103,96 | 212      | 6   |
| za16-98_Mz35   | 0,64 | 1,49 | 28,30 | 0,32 | 0,20  | 0,54  | 1,09  | 3,31  | 10,19 | 35,68 | 16,89 | 2,39 | 0,06 | 0,02  | 101,12 | 227      | 18  |
| za16-98_Mz36   | 0,70 | 1,54 | 27,82 | 0,47 | 0,23  | 0,71  | 1,29  | 3,20  | 9,98  | 33,86 | 16,37 | 2,36 | 0,10 | 0,02  | 98,67  | 210      | 17  |
| za16-98_Mz38   | 1,08 | 1,11 | 27,85 | 0,46 | 0,18  | 0,52  | 0,92  | 3,13  | 9,18  | 35,18 | 18,04 | 3,69 | 0,18 | 0,04  | 101,56 | 227      | 11  |
| za16-98_Mz39   | 0,59 | 0,50 | 29,18 | 0,44 | 0,27  | 0,78  | 1,27  | 3,20  | 10,24 | 35,00 | 17,89 | 1,59 | 0,06 | 0,01  | 101,00 | 150      | 26  |
| za16-98_Mz40   | 0,84 | 0,26 | 27,53 | 0,59 | 0,23  | 0,54  | 0,96  | 3,29  | 9,84  | 37,36 | 18,52 | 1,13 | 0,08 | 0,01  | 101,20 | 253      | 33  |
| za16-98_Mz41   | 0,70 | 0,54 | 29,32 | 0,76 | 0,30  | 0,72  | 1,09  | 3,12  | 9,66  | 34,40 | 17,78 | 1,88 | 0,11 | 0,02  | 100,40 | 190      | 20  |
| za16-98_Mz42   | 0,55 | 0,36 | 28,10 | 1,13 | 0,43  | 0,95  | 1,30  | 3,27  | 10,39 | 35,40 | 18,35 | 0,29 | 0,13 | 0,01  | 100,67 | 353      | 62  |
| za16-98_Mnz1   | 1,23 | 1,23 | 26,94 | 0,42 | 0,25  | 0,51  | 1,07  | 3,15  | 9,74  | 33,57 | 15,02 | 7,77 | 0,16 | 0,06  | 101,11 | 185      | 6   |
| za16-98_Mnz1-2 | 1,13 | 1,02 | 27,34 | 0,43 | 0,18  | 0,62  | 1,19  | 3,14  | 9,89  | 32,85 | 15,38 | 7,17 | 0,14 | 0,06  | 100,54 | 186      | 6   |
| za16-98_Mnz2-2 | 0,73 | 0,36 | 28,35 | 0,61 | 0,27  | 0,72  | 1,26  | 3,39  | 10,45 | 36,07 | 16,39 | 1,45 | 0,07 | 0,02  | 100,13 | 225      | 28  |
| za16-98_Mz3    | 0,43 | 0,27 | 29,82 | 1,05 | 0,52  | 1,51  | 2,21  | 3,36  | 11,57 | 33,35 | 18,45 | 0,00 | 0,05 | <D.L. | 102,61 | 88       | 9   |
| za16-98_Mz7    | 0,79 | 0,17 | 29,61 | 1,16 | 0,51  | 1,62  | 2,23  | 3,39  | 11,94 | 33,09 | 17,39 | 0,01 | 0,05 | <D.L. | 101,93 | 275      | 47  |
| za16-98_Mz9    | 0,72 | 0,14 | 28,58 | 0,76 | 0,36  | 0,85  | 1,40  | 3,41  | 10,74 | 36,89 | 16,51 | 0,82 | 0,10 | 0,01  | 101,30 | 204      | 40  |
| za16-98_Mz10   | 0,90 | 1,38 | 27,41 | 0,44 | 0,28  | 0,70  | 1,30  | 3,27  | 10,23 | 34,14 | 15,76 | 4,29 | 0,09 | 0,05  | 100,24 | 247      | 10  |
| za16-98_Mz15   | 0,79 | 2,58 | 27,73 | 0,40 | 0,18  | 0,58  | 1,01  | 3,16  | 9,50  | 34,18 | 17,62 | 2,50 | 0,15 | 0,03  | 100,39 | 218      | 16  |
| za16-98_Mz16   | 0,73 | 0,61 | 28,18 | 0,32 | 0,12  | 0,43  | 0,90  | 3,26  | 9,49  | 36,36 | 17,94 | 1,95 | 0,10 | 0,02  | 100,40 | 205      | 20  |
| za16-98_Mz17   | 1,13 | 0,58 | 21,80 | 0,39 | 0,13  | 0,51  | 0,91  | 3,33  | 9,94  | 38,70 | 19,34 | 3,63 | 0,16 | 0,04  | 100,58 | 256      | 11  |
| za16-98_Mz18   | 0,85 | 0,72 | 28,43 | 0,45 | 0,21  | 0,58  | 1,00  | 3,29  | 9,79  | 35,67 | 18,10 | 2,75 | 0,15 | 0,03  | 102,02 | 237      | 14  |
| za16-98_Mz23   | 0,93 | 0,22 | 28,06 | 0,58 | 0,26  | 0,55  | 1,01  | 3,20  | 9,49  | 36,10 | 18,21 | 2,15 | 0,11 | 0,02  | 100,90 | 193      | 19  |
| za16-98_Mz24   | 0,74 | 0,31 | 28,83 | 0,66 | 0,23  | 0,63  | 1,07  | 3,19  | 9,57  | 35,67 | 18,63 | 1,75 | 0,08 | 0,01  | 101,39 | 106      | 23  |
| za16-98_Mz25   | 0,58 | 0,12 | 28,74 | 0,70 | 0,29  | 0,79  | 1,24  | 3,30  | 10,26 | 35,85 | 18,75 | 1,29 | 0,11 | 0,02  | 102,04 | 271      | 29  |
| za16-98_Mz26   | 0,60 | 0,02 | 29,52 | 1,68 | 0,50  | 1,14  | 1,38  | 3,14  | 9,99  | 34,48 | 20,04 | 0,65 | 0,12 | 0,02  | 103,27 | 438      | 42  |
| za16-98_Mz27   | 0,53 | 0,02 | 30,28 | 1,44 | 0,58  | 1,13  | 1,39  | 3,06  | 10,07 | 33,16 | 19,17 | 0,58 | 0,09 | 0,00  | 101,51 | 47       | 3   |
| za16-98_Mz28   | 0,75 | 0,42 | 28,55 | 0,50 | 0,16  | 0,53  | 1,00  | 3,17  | 9,44  | 35,41 | 17,91 | 2,28 | 0,08 | 0,03  | 100,22 | 255      | 19  |

| SESSION 2        |          |      |       |      |       |       |       |       |       |       |       |      |          |      |        |          |     |
|------------------|----------|------|-------|------|-------|-------|-------|-------|-------|-------|-------|------|----------|------|--------|----------|-----|
| Sample No.       | ZAL18-11 |      |       |      |       |       |       |       |       |       |       |      |          |      |        |          |     |
| D.L. (ppm)       | CaO      | SiO2 | P2O5  | Y2O3 | Dy2O3 | Gd2O3 | Sm2O3 | Pr2O3 | Nd2O3 | Ce2O3 | La2O3 | ThO2 | UO2 Corr | PbO  | TOTAL  | Age (Ma) | Std |
|                  | 101      | 41   | 288   | 228  | 729   | 649   | 563   | 527   | 341   | 385   | 414   | 141  | 142      | 101  |        |          |     |
| ZAL18-11-Mnz3    | 1,07     | 0,22 | 30,13 | 2,01 | 0,59  | 1,43  | 1,83  | 3,23  | 12,30 | 29,29 | 14,75 | 4,45 | 0,72     | 0,07 | 102,10 | 259      | 8   |
| ZAL18-11-Mnz1-5  | 0,28     | 0,52 | 29,28 | 0,25 | 0,20  | 1,40  | 2,09  | 3,39  | 13,40 | 33,52 | 14,58 | 2,95 | 0,04     | 0,04 | 101,93 | 275      | 16  |
| ZAL18-11-Mnz2    | 0,60     | 0,20 | 30,49 | 1,45 | 0,59  | 1,45  | 1,95  | 3,32  | 12,73 | 30,60 | 15,50 | 2,75 | 0,37     | 0,05 | 102,04 | 325      | 12  |
| ZAL18-11-Mnz3-2  | 0,30     | 0,22 | 29,53 | 0,25 | 0,20  | 0,97  | 1,76  | 3,30  | 12,29 | 34,37 | 16,19 | 1,50 | 0,01     | 0,01 | 100,92 | 203      | 32  |
| ZAL18-11-Mnz3-3  | 0,55     | 0,35 | 29,28 | 0,29 | 0,16  | 1,09  | 2,18  | 3,49  | 14,69 | 32,33 | 13,79 | 2,96 | 0,06     | 0,03 | 101,24 | 212      | 16  |
| ZAL18-11-Mnz3-4  | 0,55     | 0,14 | 29,75 | 0,40 | 0,19  | 1,11  | 1,81  | 3,22  | 12,20 | 33,16 | 17,35 | 1,18 | 0,03     | 0,01 | 101,10 | 204      | 39  |
| ZAL18-11-Mnz3-6  | 0,64     | 0,25 | 30,02 | 1,19 | 0,49  | 1,47  | 1,78  | 3,11  | 11,65 | 33,03 | 15,21 | 3,08 | 0,30     | 0,04 | 102,28 | 258      | 12  |
| ZAL18-11-Mnz3-7  | 0,33     | 0,38 | 29,14 | 0,24 | 0,20  | 0,96  | 1,83  | 3,39  | 12,83 | 33,68 | 15,52 | 2,56 | 0,04     | 0,03 | 101,13 | 229      | 18  |
| ZAL18-11-Mnz3-8  | 0,38     | 0,29 | 29,72 | 1,06 | 0,39  | 1,15  | 1,51  | 3,05  | 11,37 | 33,73 | 16,17 | 2,39 | 0,13     | 0,03 | 101,39 | 235      | 17  |
| ZAL18-11-Mnz3-9  | 0,99     | 0,31 | 29,62 | 0,72 | 0,37  | 1,45  | 1,96  | 3,17  | 12,83 | 31,96 | 13,25 | 4,99 | 0,26     | 0,06 | 101,91 | 232      | 9   |
| ZAL18-11-Mnz3-10 | 0,53     | 0,19 | 29,83 | 0,75 | 0,26  | 1,07  | 1,71  | 3,22  | 11,99 | 33,62 | 16,63 | 1,44 | 0,05     | 0,01 | 101,30 | 209      | 31  |
| ZAL18-11-Mnz3-11 | 0,39     | 0,20 | 29,93 | 1,07 | 0,35  | 0,98  | 1,42  | 3,06  | 11,39 | 33,85 | 17,16 | 1,85 | 0,14     | 0,02 | 101,80 | 200      | 22  |
| ZAL18-11-Mnz3-12 | 1,04     | 0,28 | 29,88 | 0,39 | 0,23  | 1,20  | 1,90  | 3,23  | 12,62 | 32,06 | 14,17 | 4,74 | 0,18     | 0,06 | 101,97 | 270      | 10  |
| ZAL18-11-Mnz5-3  | 0,59     | 2,85 | 27,91 | 0,31 | 0,13  | 0,95  | 1,24  | 2,86  | 10,55 | 30,48 | 17,04 | 0,63 | 0,01     | 0,01 | 95,59  | 403      | 72  |
| ZAL18-11-Mnz6-1  | 2,54     | 0,34 | 28,50 | 1,71 | 0,52  | 1,37  | 1,99  | 3,08  | 11,34 | 27,18 | 12,89 | 8,53 | 2,14     | 0,06 | 102,18 | 90       | 3   |
| ZAL18-11-Mnz8-1  | 0,66     | 0,69 | 29,83 | 1,32 | 0,47  | 1,35  | 2,15  | 3,36  | 13,36 | 30,23 | 14,43 | 1,85 | 0,43     | 0,03 | 100,15 | 197      | 16  |
| ZAL18-11-Mnz8-2  | 1,18     | 1,31 | 29,93 | 0,84 | 0,32  | 1,31  | 2,24  | 3,35  | 13,19 | 29,16 | 13,50 | 3,51 | 0,84     | 0,06 | 100,75 | 243      | 8   |
| ZAL18-11-Mnz9-1  | 0,96     | 0,18 | 29,78 | 0,65 | 0,32  | 1,44  | 2,58  | 3,54  | 14,75 | 30,17 | 13,18 | 1,60 | 0,18     | 0,02 | 99,34  | 185      | 23  |
| ZAL18-11-Mnz9-6  | 0,95     | 1,41 | 29,85 | 0,40 | 0,24  | 1,21  | 2,16  | 3,40  | 13,48 | 31,40 | 14,61 | 1,09 | 0,08     | 0,01 | 100,30 | 180      | 37  |
| ZAL18-11-Mnz6    | 2,84     | 0,34 | 29,14 | 1,76 | 0,56  | 1,49  | 2,03  | 3,08  | 11,54 | 26,68 | 12,22 | 7,61 | 0,98     | 0,12 | 100,37 | 90       | 3   |
| ZAL18-11-Mnz6-3  | 2,84     | 0,32 | 29,87 | 1,76 | 0,55  | 1,51  | 2,14  | 3,27  | 11,99 | 27,93 | 12,84 | 7,40 | 0,57     | 0,06 | 103,03 | 160      | 6   |
| ZAL18-11-Mnz6-4  | 2,93     | 0,16 | 29,84 | 1,15 | 0,41  | 1,43  | 2,16  | 3,20  | 12,19 | 29,25 | 15,04 | 4,69 | 0,70     | 0,07 | 103,21 | 234      | 7   |

| Sample     | $^{207}\text{Pb}/^{235}\text{U}$ | Error $2\sigma$ | $^{206}\text{Pb}/^{238}\text{U}$ | Error $2\sigma$ | correlation_6_38 | $^{238}\text{U}/^{206}\text{Pb}$ |
|------------|----------------------------------|-----------------|----------------------------------|-----------------|------------------|----------------------------------|
| T_MKED1_1  | 3.830                            | 0.200           | 0.271                            | 0.006           | 0.185            | 3.685                            |
| T_MKED1_2  | 3.469                            | 0.067           | 0.262                            | 0.005           | 0.295            | 3.824                            |
| T_MKED1_3  | 3.830                            | 0.550           | 0.270                            | 0.006           | -0.010           | 3.708                            |
| T_MKED1_4  | 3.480                            | 0.074           | 0.263                            | 0.005           | 0.795            | 3.797                            |
| T_MKED1_5  | 3.452                            | 0.068           | 0.269                            | 0.006           | 0.266            | 3.723                            |
| T_MKED1_6  | 3.387                            | 0.068           | 0.258                            | 0.005           | 0.630            | 3.880                            |
| T_MKED1_7  | 3.497                            | 0.080           | 0.263                            | 0.005           | 0.276            | 3.804                            |
| T_MKED1_8  | 3.534                            | 0.091           | 0.267                            | 0.006           | 0.859            | 3.751                            |
| T_MKED1_9  | 3.400                            | 0.110           | 0.261                            | 0.004           | 0.227            | 3.837                            |
| T_MKED1_10 | 3.580                            | 0.110           | 0.265                            | 0.006           | 0.505            | 3.771                            |
| T_MKED1_11 | 3.389                            | 0.094           | 0.260                            | 0.005           | 0.346            | 3.849                            |
| T_MKED1_12 | 3.605                            | 0.089           | 0.272                            | 0.006           | 0.262            | 3.679                            |
| T_MKED1_13 | 3.620                            | 0.082           | 0.273                            | 0.005           | 0.664            | 3.662                            |
| T_MKED1_14 | 3.740                            | 0.110           | 0.272                            | 0.005           | 0.078            | 3.674                            |
| T_MKED1_15 | 3.680                            | 0.110           | 0.281                            | 0.007           | 0.475            | 3.557                            |
| T_MKED1_16 | 3.570                            | 0.130           | 0.269                            | 0.005           | 0.673            | 3.720                            |
| T_MKED1_17 | 3.650                            | 0.110           | 0.274                            | 0.006           | 0.596            | 3.650                            |
| T_MKED1_18 | 3.491                            | 0.076           | 0.265                            | 0.007           | 0.648            | 3.774                            |
| T_MKED1_19 | 3.570                            | 0.160           | 0.265                            | 0.006           | 0.810            | 3.774                            |
| T_MKED1_20 | 3.570                            | 0.150           | 0.268                            | 0.006           | 0.010            | 3.727                            |
| T_MKED1_21 | 3.370                            | 0.140           | 0.257                            | 0.006           | 0.381            | 3.894                            |
| T_MKED1_22 | 3.641                            | 0.092           | 0.279                            | 0.006           | 0.672            | 3.583                            |
| T_MKED1_23 | 3.650                            | 0.120           | 0.274                            | 0.007           | 0.963            | 3.652                            |
| T_MKED1_24 | 3.880                            | 0.270           | 0.269                            | 0.007           | 0.013            | 3.717                            |
| T_MKED1_25 | 3.650                            | 0.240           | 0.264                            | 0.007           | 0.842            | 3.782                            |
| T_MKED1_26 | 4.800                            | 1.200           | 0.272                            | 0.007           | 0.446            | 3.682                            |
| T_MKED1_27 | 3.700                            | 0.260           | 0.259                            | 0.005           | 0.876            | 3.867                            |
| T_MKED1_28 | 3.590                            | 0.100           | 0.268                            | 0.006           | 0.406            | 3.736                            |
| T_MKED1_29 | 3.682                            | 0.089           | 0.277                            | 0.006           | 0.148            | 3.614                            |
| T_MKED1_30 | 3.360                            | 0.110           | 0.259                            | 0.007           | 0.426            | 3.864                            |
| T_MKED1_31 | 4.040                            | 0.290           | 0.285                            | 0.008           | 0.462            | 3.506                            |
| T_MKED1_32 | 3.680                            | 0.100           | 0.278                            | 0.008           | 0.439            | 3.604                            |
| T_MKED1_33 | 3.448                            | 0.095           | 0.262                            | 0.005           | 0.351            | 3.811                            |
| T_MKED1_34 | 4.080                            | 0.330           | 0.282                            | 0.012           | 0.567            | 3.546                            |
| T_MKED1_35 | 3.990                            | 0.330           | 0.274                            | 0.007           | 0.317            | 3.647                            |
| T_MKED1_36 | 3.590                            | 0.150           | 0.272                            | 0.006           | 0.272            | 3.681                            |
| X16_ttn_1  | 429.000                          | 36.000          | 3.720                            | 0.300           | 0.963            | 0.269                            |
| X16_ttn_2  | 329.000                          | 28.000          | 2.880                            | 0.250           | 0.989            | 0.347                            |
| X16_ttn_3  | 154.000                          | 25.000          | 1.320                            | 0.180           | 0.715            | 0.758                            |
| X16_ttn_4  | 601.000                          | 38.000          | 5.270                            | 0.320           | 0.966            | 0.190                            |
| X16_ttn_5  | 104.000                          | 11.000          | 0.938                            | 0.098           | 0.975            | 1.066                            |
| X16_ttn_6  | 237.000                          | 28.000          | 2.120                            | 0.250           | 0.983            | 0.472                            |
| X16_ttn_7  | 40.900                           | 3.500           | 0.410                            | 0.033           | 0.564            | 2.439                            |
| X16_ttn_8  | 1360.000                         | 120.000         | 11.900                           | 1.100           | 0.985            | 0.084                            |
| X16_ttn_9  | 758.000                          | 51.000          | 6.630                            | 0.450           | 0.817            | 0.151                            |
| X16_ttn_10 | 268.000                          | 14.000          | 2.330                            | 0.130           | 0.348            | 0.429                            |
| X16_ttn_11 | 181.000                          | 13.000          | 1.595                            | 0.092           | 0.940            | 0.627                            |
| X16_ttn_12 | 1700.000                         | 210.000         | 14.300                           | 1.700           | 0.990            | 0.070                            |

|            |               |          |             |            |       |        |
|------------|---------------|----------|-------------|------------|-------|--------|
| X16_ttn_13 | 181.000       | 29.000   | 1.630       | 0.270      | 0.992 | 0.613  |
| X16_ttn_14 | 288.000       | 12.000   | 2.550       | 0.120      | 0.910 | 0.392  |
| X16_ttn_15 | 1359.000      | 47.000   | 11.680      | 0.410      | 0.915 | 0.086  |
| X16_ttn_16 | 1497.000      | 54.000   | 12.960      | 0.500      | 0.943 | 0.077  |
| X16_ttn_17 | 1660.000      | 130.000  | 14.500      | 1.300      | 0.249 | 0.069  |
| X16_ttn_18 | 2120.000      | 250.000  | 18.500      | 2.200      | 0.993 | 0.054  |
| X16_ttn_19 | 1519.000      | 59.000   | 12.970      | 0.640      | 0.015 | 0.077  |
| X16_ttn_20 | 9010.000      | 510.000  | 77.800      | 4.400      | 0.983 | 0.013  |
| X16_ttn_21 | 349.000       | 20.000   | 3.070       | 0.180      | 0.990 | 0.326  |
| X16_ttn_22 | 142.000       | 13.000   | 1.290       | 0.110      | 0.978 | 0.775  |
| X16_ttn_23 | 174.000       | 24.000   | 1.430       | 0.180      | 0.848 | 0.699  |
| X16_ttn_24 | 52.200        | 3.700    | 0.501       | 0.034      | 0.857 | 1.996  |
| X16_ttn_25 | 46.500        | 1.500    | 0.454       | 0.014      | 0.791 | 2.203  |
| X16_ttn_26 | 113.600       | 3.400    | 1.024       | 0.033      | 0.926 | 0.977  |
| X16_ttn_27 | 111.200       | 3.900    | 0.989       | 0.037      | 0.904 | 1.011  |
| X16_ttn_28 | 4350.000      | 900.000  | 41.400      | 9.500      | 0.607 | 0.024  |
| X16_ttn_29 | 1757.000      | 72.000   | 14.900      | 0.650      | 0.946 | 0.067  |
| X16_ttn_30 | 1850.000      | 150.000  | 16.000      | 1.200      | 0.987 | 0.063  |
| X16_ttn_31 | 5390.000      | 510.000  | 46.400      | 4.500      | 0.987 | 0.022  |
| X16_ttn_32 | 138.000       | 19.000   | 1.220       | 0.170      | 0.973 | 0.820  |
| X16_ttn_33 | 1159.000      | 76.000   | 9.960       | 0.680      | 0.951 | 0.100  |
| X16_ttn_34 | -25000000.000 | #####    | -180000.000 | 130000.000 | 0.997 | 0.000  |
| X16_ttn_35 | 1051.000      | 96.000   | 8.500       | 0.670      | 0.844 | 0.118  |
| X16_ttn_36 | 4080.000      | 670.000  | 33.800      | 5.400      | 0.998 | 0.030  |
| X16_ttn_37 | 8.000         | 1.700    | 0.118       | 0.014      | 0.956 | 8.475  |
| X16_ttn_38 | 143.900       | 9.400    | 1.285       | 0.078      | 0.922 | 0.778  |
| X16_ttn_39 | 3.050         | 0.160    | 0.075       | 0.002      | 0.139 | 13.369 |
| X16_ttn_40 | 151.000       | 10.000   | 1.341       | 0.082      | 0.882 | 0.746  |
| X16_ttn_41 | 294.000       | 29.000   | 2.580       | 0.260      | 0.987 | 0.388  |
| X16_ttn_42 | 220.000       | 11.000   | 1.930       | 0.086      | 0.978 | 0.518  |
|            |               |          |             |            |       |        |
| X82_ttn_1  | 1020.000      | 190.000  | 8.900       | 1.600      | 0.997 | 0.112  |
| X82_ttn_2  | 256.000       | 20.000   | 2.260       | 0.180      | 0.980 | 0.442  |
| X82_ttn_3  | 71.100        | 4.300    | 0.685       | 0.045      | 0.986 | 1.460  |
| X82_ttn_4  | 274.000       | 36.000   | 2.450       | 0.300      | 0.990 | 0.408  |
| X82_ttn_5  | 12800.000     | 2500.000 | 110.000     | 23.000     | 0.993 | 0.009  |
| X82_ttn_6  | 8200.000      | 1000.000 | 73.600      | 9.700      | 0.900 | 0.014  |
| X82_ttn_7  | 356.000       | 76.000   | 3.100       | 0.660      | 0.986 | 0.323  |
| X82_ttn_8  | 258.000       | 22.000   | 2.240       | 0.170      | 0.859 | 0.446  |
| X82_ttn_9  | 187.000       | 19.000   | 1.700       | 0.170      | 0.987 | 0.588  |
| X82_ttn_10 | 459.000       | 18.000   | 3.970       | 0.150      | 0.941 | 0.252  |
| X82_ttn_11 | 627.000       | 54.000   | 5.560       | 0.490      | 0.046 | 0.180  |
| X82_ttn_12 | 47000.000     | #####    | 384.000     | 75.000     | 0.983 | 0.003  |
| X82_ttn_13 | 3.420         | 0.350    | 0.080       | 0.005      | 0.913 | 12.516 |
| X82_ttn_14 | 1.996         | 0.043    | 0.067       | 0.002      | 0.289 | 15.015 |
| X82_ttn_15 | 7.690         | 0.240    | 0.116       | 0.003      | 0.826 | 8.591  |
| X82_ttn_16 | 33.000        | 3.000    | 0.337       | 0.027      | 0.934 | 2.967  |
| X82_ttn_17 | 5.860         | 0.350    | 0.103       | 0.004      | 0.908 | 9.709  |
| X82_ttn_18 | 5.180         | 0.490    | 0.093       | 0.005      | 0.884 | 10.753 |
| X82_ttn_19 | 8.000         | 1.300    | 0.111       | 0.009      | 0.601 | 9.050  |

|            |          |        |       |       |        |        |
|------------|----------|--------|-------|-------|--------|--------|
| X82_ttn_20 | 15.600   | 0.980  | 0.184 | 0.008 | 0.927  | 5.441  |
| X82_ttn_21 | 137.000  | 13.000 | 1.200 | 0.110 | 0.899  | 0.833  |
| X82_ttn_22 | 6.260    | 0.240  | 0.107 | 0.004 | 0.852  | 9.346  |
| X82_ttn_23 | 2.890    | 0.130  | 0.073 | 0.003 | 0.762  | 13.680 |
| X82_ttn_24 | 7.290    | 0.300  | 0.115 | 0.003 | 0.514  | 8.688  |
| X82_ttn_25 | 4.400    | 0.430  | 0.086 | 0.006 | 0.916  | 11.601 |
| X82_ttn_26 | 77.100   | 4.700  | 0.712 | 0.040 | 0.985  | 1.404  |
| X82_ttn_27 | 107.900  | 7.200  | 0.997 | 0.064 | 0.886  | 1.003  |
| X82_ttn_28 | 144.000  | 12.000 | 1.340 | 0.120 | 0.599  | 0.746  |
| X82_ttn_29 | 18.200   | 1.300  | 0.208 | 0.018 | 0.535  | 4.808  |
| X82_ttn_30 | 17.820   | 0.780  | 0.204 | 0.009 | 0.887  | 4.912  |
| X82_ttn_31 | 57.500   | 5.100  | 0.553 | 0.046 | 0.973  | 1.808  |
| X82_ttn_32 | 175.100  | 6.000  | 1.564 | 0.052 | 0.941  | 0.639  |
| X82_ttn_33 | 432.000  | 19.000 | 3.760 | 0.160 | 0.882  | 0.266  |
| X82_ttn_34 | 223.900  | 5.700  | 2.006 | 0.051 | 0.882  | 0.499  |
| X82_ttn_35 | 169.500  | 9.800  | 1.507 | 0.083 | 0.770  | 0.664  |
| X82_ttn_36 | 205.900  | 7.000  | 1.801 | 0.048 | 0.373  | 0.555  |
| X82_ttn_37 | 319.000  | 29.000 | 2.990 | 0.320 | 0.610  | 0.334  |
| X82_ttn_38 | 236.000  | 12.000 | 2.010 | 0.093 | 0.523  | 0.498  |
| X82_ttn_39 | 355.000  | 13.000 | 3.050 | 0.110 | 0.931  | 0.328  |
| X82_ttn_40 | 200.000  | 11.000 | 1.743 | 0.082 | 0.961  | 0.574  |
| X82_ttn_41 | 243.000  | 11.000 | 2.180 | 0.100 | 0.913  | 0.459  |
| X82_ttn_42 | 131.500  | 9.800  | 1.330 | 0.220 | 0.203  | 0.752  |
| X82_ttn_43 | 75.100   | 6.200  | 0.670 | 0.049 | 0.147  | 1.493  |
| X82_ttn_44 | 207.200  | 8.400  | 1.805 | 0.074 | 0.921  | 0.554  |
| X82_ttn_45 | 1019.000 | 83.000 | 8.990 | 0.720 | 0.980  | 0.111  |
| X82_ttn_46 | 75.700   | 3.100  | 0.678 | 0.021 | 0.052  | 1.475  |
| X82_ttn_47 | 452.000  | 16.000 | 3.880 | 0.140 | 0.655  | 0.258  |
| X82_ttn_48 | 122.800  | 6.400  | 1.084 | 0.040 | 0.343  | 0.923  |
| X82_ttn_49 | 226.000  | 36.000 | 1.940 | 0.290 | 0.982  | 0.515  |
| X82_ttn_50 | 95.600   | 3.500  | 0.857 | 0.030 | 0.859  | 1.167  |
| X82_ttn_51 | 330.000  | 26.000 | 2.890 | 0.220 | 0.961  | 0.346  |
| X82_ttn_52 | 166.500  | 9.800  | 1.540 | 0.110 | 0.911  | 0.649  |
| X82_ttn_53 | 530.000  | 84.000 | 4.420 | 0.680 | 0.768  | 0.226  |
| X82_ttn_54 | 771.000  | 51.000 | 6.740 | 0.400 | 0.959  | 0.148  |
| X82_ttn_55 | 360.000  | 13.000 | 3.190 | 0.140 | 0.317  | 0.313  |
| X82_ttn_56 | 29.600   | 2.100  | 0.293 | 0.017 | 0.870  | 3.413  |
| X82_ttn_57 | 190.000  | 36.000 | 1.590 | 0.300 | 0.988  | 0.629  |
| X82_ttn_58 | 33.500   | 3.200  | 0.333 | 0.028 | 0.961  | 3.003  |
| X82_ttn_59 | 39.100   | 2.700  | 0.402 | 0.028 | 0.739  | 2.488  |
| X82_ttn_60 | 144.000  | 27.000 | 1.200 | 0.190 | 0.998  | 0.833  |
| X82_ttn_61 | 168.000  | 14.000 | 1.500 | 0.100 | 0.901  | 0.667  |
| X82_ttn_62 | 38.700   | 2.100  | 0.393 | 0.022 | 0.165  | 2.545  |
|            |          |        |       |       |        |        |
| X84_ttn_1  | 164.000  | 35.000 | 1.590 | 0.360 | 0.994  | 0.629  |
| X84_ttn_2  | 48.900   | 6.200  | 0.455 | 0.047 | -0.059 | 2.198  |
| X84_ttn_3  | 55.600   | 4.800  | 0.542 | 0.044 | 0.296  | 1.845  |
| X84_ttn_4  | 63.400   | 5.700  | 0.583 | 0.044 | 0.695  | 1.715  |
| X84_ttn_5  | 125.000  | 13.000 | 1.110 | 0.120 | 0.931  | 0.901  |
| X84_ttn_6  | 111.000  | 23.000 | 0.980 | 0.200 | 0.978  | 1.020  |



|             |         |         |       |       |        |        |
|-------------|---------|---------|-------|-------|--------|--------|
| X84_ttn_7   | 92.600  | 4.600   | 0.862 | 0.045 | 0.703  | 1.160  |
| X84_ttn_8   | 524.000 | 66.000  | 4.550 | 0.570 | 0.982  | 0.220  |
| X84_ttn_9   | 4.140   | 0.890   | 0.082 | 0.007 | 0.038  | 12.255 |
| X84_ttn_10  | 44.400  | 4.500   | 0.420 | 0.036 | 0.061  | 2.381  |
| X84_ttn_11  | 37.000  | 3.300   | 0.362 | 0.033 | 0.852  | 2.762  |
| X84_ttn_12  | 58.000  | 9.000   | 0.537 | 0.078 | 0.965  | 1.862  |
| X84_ttn_13  | 83.300  | 7.200   | 0.755 | 0.057 | 0.712  | 1.325  |
| X84_ttn_14  | 101.000 | 14.000  | 0.880 | 0.110 | 0.306  | 1.136  |
| X84_ttn_15  | 44.700  | 2.800   | 0.442 | 0.023 | 0.255  | 2.262  |
| X84_ttn_16  | 154.600 | 8.500   | 1.420 | 0.170 | 0.884  | 0.704  |
| X84_ttn_17  | 163.000 | 10.000  | 1.482 | 0.095 | 0.189  | 0.675  |
| X84_ttn_18  | 610.000 | 140.000 | 5.600 | 1.300 | 0.982  | 0.179  |
| X84_ttn_19  | 26.200  | 3.900   | 0.286 | 0.033 | 0.556  | 3.497  |
| X84_ttn_20  | 280.000 | 49.000  | 2.550 | 0.400 | 0.768  | 0.392  |
| X84_ttn_21  | 296.000 | 35.000  | 2.510 | 0.290 | 0.658  | 0.398  |
| X84_ttn_22  | 169.000 | 27.000  | 1.367 | 0.078 | 0.243  | 0.732  |
| X84_ttn_23  | 106.700 | 5.900   | 0.995 | 0.094 | 0.917  | 1.005  |
| X84_ttn_24  | 772.000 | 82.000  | 7.500 | 1.200 | 0.360  | 0.133  |
| X84_ttn_25  | 21.400  | 1.500   | 0.236 | 0.013 | 0.338  | 4.237  |
| X84_ttn_26  | 401.000 | 40.000  | 3.570 | 0.360 | 0.346  | 0.280  |
| X84_ttn_27  | 87.900  | 7.100   | 0.800 | 0.100 | 0.536  | 1.250  |
| X84_ttn_28  | 117.000 | 17.000  | 1.240 | 0.240 | 0.455  | 0.806  |
| X84_ttn_29  | 880.000 | 150.000 | 8.000 | 1.500 | 0.954  | 0.125  |
| X84_ttn_30  | 166.000 | 15.000  | 1.405 | 0.063 | 0.037  | 0.712  |
| X84_ttn_31  | 13.140  | 0.850   | 0.161 | 0.008 | 0.885  | 6.219  |
| X84_ttn_32  | 90.100  | 9.800   | 0.823 | 0.082 | 0.653  | 1.215  |
| X84_ttn_33  | 72.000  | 14.000  | 0.750 | 0.150 | 0.640  | 1.333  |
| X84_ttn_34  | 83.400  | 9.900   | 0.776 | 0.095 | 0.458  | 1.289  |
| X84_ttn_35  | 2.110   | 0.190   | 0.065 | 0.002 | 0.422  | 15.432 |
| X84_ttn_36  | 11.300  | 1.500   | 0.144 | 0.014 | 0.257  | 6.944  |
| X84_ttn_37  | 207.000 | 12.000  | 1.810 | 0.110 | -0.128 | 0.552  |
| X84_ttn_38  | 102.000 | 14.000  | 0.940 | 0.120 | 0.104  | 1.064  |
| X84_ttn_39  | 120.000 | 20.000  | 1.340 | 0.740 | 0.899  | 0.746  |
| X84_ttn_40  | 158.800 | 8.800   | 1.423 | 0.067 | 0.627  | 0.703  |
| X84_ttn_41  | 176.000 | 27.000  | 1.460 | 0.200 | 0.707  | 0.685  |
| X84_ttn_42  | 128.200 | 9.100   | 1.196 | 0.073 | 0.876  | 0.836  |
| X84_ttn_43  | 201.000 | 40.000  | 1.640 | 0.290 | 0.376  | 0.610  |
| X84_ttn_44  | 346.000 | 38.000  | 3.800 | 1.100 | 0.445  | 0.263  |
| X117_ttn_1  | 173.000 | 18.000  | 1.680 | 0.190 | 0.272  | 0.595  |
| X117_ttn_2  | 87.000  | 10.000  | 0.796 | 0.081 | 0.994  | 1.256  |
| X117_ttn_3  | 235.100 | 7.500   | 2.127 | 0.066 | 0.901  | 0.470  |
| X117_ttn_4  | 470.000 | 26.000  | 4.070 | 0.230 | 0.984  | 0.246  |
| X117_ttn_5  | 317.500 | 9.100   | 2.850 | 0.100 | 0.321  | 0.351  |
| X117_ttn_6  | 512.000 | 51.000  | 4.290 | 0.390 | 0.776  | 0.233  |
| X117_ttn_7  | 640.000 | 35.000  | 5.640 | 0.300 | 0.979  | 0.177  |
| X117_ttn_8  | 722.000 | 33.000  | 6.400 | 0.300 | 0.972  | 0.156  |
| X117_ttn_9  | 134.600 | 5.400   | 1.234 | 0.040 | 0.464  | 0.810  |
| X117_ttn_10 | 257.600 | 7.700   | 2.335 | 0.068 | 0.206  | 0.428  |
| X117_ttn_11 | 378.900 | 8.900   | 3.416 | 0.091 | 0.789  | 0.293  |

|             |          |         |        |       |        |       |
|-------------|----------|---------|--------|-------|--------|-------|
| X117_ttn_12 | 281.000  | 16.000  | 2.570  | 0.140 | 0.952  | 0.389 |
| X117_ttn_13 | 931.000  | 85.000  | 8.430  | 0.790 | 0.995  | 0.119 |
| X117_ttn_14 | 201.000  | 11.000  | 1.820  | 0.092 | 0.585  | 0.549 |
| X117_ttn_15 | 378.000  | 36.000  | 3.370  | 0.310 | 0.864  | 0.297 |
| X117_ttn_16 | 727.000  | 39.000  | 6.430  | 0.330 | 0.894  | 0.156 |
| X117_ttn_17 | 630.000  | 110.000 | 6.000  | 1.100 | 0.407  | 0.167 |
| X117_ttn_18 | 274.000  | 16.000  | 2.450  | 0.140 | 0.983  | 0.408 |
| X117_ttn_19 | 263.000  | 13.000  | 2.350  | 0.120 | 0.553  | 0.426 |
| X117_ttn_20 | 520.000  | 34.000  | 4.560  | 0.240 | 0.908  | 0.219 |
| X117_ttn_21 | 298.000  | 11.000  | 2.720  | 0.110 | 0.901  | 0.368 |
| X117_ttn_22 | 1164.000 | 47.000  | 10.570 | 0.420 | 0.961  | 0.095 |
| X117_ttn_23 | 414.000  | 29.000  | 3.560  | 0.240 | 0.981  | 0.281 |
| X117_ttn_24 | 224.000  | 10.000  | 2.052  | 0.094 | 0.911  | 0.487 |
| X117_ttn_25 | 262.000  | 14.000  | 2.380  | 0.120 | 0.600  | 0.420 |
| X117_ttn_26 | 261.000  | 20.000  | 2.330  | 0.170 | 0.988  | 0.429 |
| X117_ttn_27 | 283.000  | 31.000  | 2.500  | 0.260 | 0.851  | 0.400 |
| X117_ttn_28 | 132.200  | 7.200   | 1.202  | 0.060 | 0.657  | 0.832 |
| X117_ttn_29 | 753.000  | 26.000  | 6.650  | 0.240 | 0.968  | 0.150 |
| X117_ttn_30 | 1170.000 | 100.000 | 10.480 | 0.950 | 0.986  | 0.095 |
| X117_ttn_31 | 401.000  | 35.000  | 3.460  | 0.280 | 0.945  | 0.289 |
| X117_ttn_32 | 63.300   | 2.700   | 0.594  | 0.026 | 0.733  | 1.684 |
| X117_ttn_33 | 291.000  | 14.000  | 2.600  | 0.130 | 0.337  | 0.385 |
| X117_ttn_34 | 224.800  | 8.300   | 2.023  | 0.079 | 0.911  | 0.494 |
| X117_ttn_35 | 322.000  | 15.000  | 2.840  | 0.130 | 0.978  | 0.352 |
| X117_ttn_36 | 890.000  | 120.000 | 7.900  | 1.000 | 0.992  | 0.127 |
| X117_ttn_37 | 305.000  | 15.000  | 2.680  | 0.140 | 0.440  | 0.373 |
| X117_ttn_38 | 329.000  | 35.000  | 2.920  | 0.300 | 0.991  | 0.342 |
| X117_ttn_39 | 609.000  | 72.000  | 5.120  | 0.590 | 0.969  | 0.195 |
| X117_ttn_40 | 323.000  | 19.000  | 2.860  | 0.150 | 0.966  | 0.350 |
| X117_ttn_41 | 248.000  | 29.000  | 2.240  | 0.260 | 0.969  | 0.446 |
| X117_ttn_42 | 428.000  | 46.000  | 3.710  | 0.390 | 0.987  | 0.270 |
| X117_ttn_43 | 725.000  | 42.000  | 6.720  | 0.400 | 0.908  | 0.149 |
| X117_ttn_44 | 569.000  | 63.000  | 4.830  | 0.460 | 0.949  | 0.207 |
| X117_ttn_45 | 347.000  | 46.000  | 3.100  | 0.390 | 0.969  | 0.323 |
| X117_ttn_46 | 247.000  | 19.000  | 2.210  | 0.170 | 0.878  | 0.452 |
| X117_ttn_47 | 421.000  | 29.000  | 3.710  | 0.260 | 0.981  | 0.270 |
| X117_ttn_48 | 289.000  | 23.000  | 2.640  | 0.220 | 0.975  | 0.379 |
| X117_ttn_49 | 142.600  | 9.100   | 1.317  | 0.080 | 0.847  | 0.759 |
| X117_ttn_50 | 134.900  | 4.400   | 1.241  | 0.040 | 0.961  | 0.806 |
| X117_ttn_51 | 259.000  | 16.000  | 2.300  | 0.140 | 0.959  | 0.435 |
| X117_ttn_52 | 89.700   | 7.800   | 0.853  | 0.075 | 0.985  | 1.172 |
| X117_ttn_53 | 329.000  | 17.000  | 2.840  | 0.120 | 0.550  | 0.352 |
| X117_ttn_54 | 132.500  | 3.200   | 1.207  | 0.041 | 0.587  | 0.829 |
| X117_ttn_55 | 79.400   | 2.900   | 0.748  | 0.019 | -0.023 | 1.337 |
| X117_ttn_56 | 208.800  | 8.600   | 1.879  | 0.076 | 0.722  | 0.532 |
| X117_ttn_57 | 332.000  | 23.000  | 2.970  | 0.200 | 0.988  | 0.337 |
| X117_ttn_58 | 144.000  | 14.000  | 1.310  | 0.130 | 0.778  | 0.763 |
| X117_ttn_59 | 97.700   | 3.800   | 0.911  | 0.037 | 0.688  | 1.098 |
| X117_ttn_60 | 108.000  | 6.600   | 0.963  | 0.046 | 0.499  | 1.038 |
| X117_ttn_61 | 103.000  | 4.200   | 0.941  | 0.037 | 0.772  | 1.063 |

|              |          |         |        |       |        |       |
|--------------|----------|---------|--------|-------|--------|-------|
| X117_ttn_62  | 224.800  | 5.600   | 2.063  | 0.054 | -0.010 | 0.485 |
| X117_ttn_63  | 13.690   | 0.810   | 0.170  | 0.007 | 0.826  | 5.869 |
| X117_ttn_64  | 35.900   | 1.200   | 0.370  | 0.011 | 0.833  | 2.703 |
| X117_ttn_65  | 80.800   | 8.600   | 0.731  | 0.072 | 0.486  | 1.368 |
| X117_ttn_66  | 193.200  | 6.800   | 1.750  | 0.089 | 0.705  | 0.571 |
| X117_ttn_67  | 46.200   | 7.400   | 0.433  | 0.060 | 0.813  | 2.309 |
| X117_ttn_68  | 219.000  | 14.000  | 1.940  | 0.120 | 0.898  | 0.515 |
| X117_ttn_69  | 597.000  | 48.000  | 5.440  | 0.460 | 0.993  | 0.184 |
| X117_ttn_70  | 271.500  | 6.300   | 2.408  | 0.065 | 0.807  | 0.415 |
| X117_ttn_71  | 241.000  | 14.000  | 2.180  | 0.130 | 0.955  | 0.459 |
| X117_ttn_72  | 375.000  | 13.000  | 3.320  | 0.120 | 0.969  | 0.301 |
| X117_ttn_73  | 422.000  | 16.000  | 3.770  | 0.150 | 0.933  | 0.265 |
| X117_ttn_74  | 1200.000 | 130.000 | 10.960 | 0.750 | 0.344  | 0.091 |
| X117_ttn_75  | 284.000  | 14.000  | 2.570  | 0.180 | 0.877  | 0.389 |
| X117_ttn_76  | 192.000  | 11.000  | 1.770  | 0.140 | 0.376  | 0.565 |
| X117_ttn_77  | 404.000  | 19.000  | 3.660  | 0.160 | 0.952  | 0.273 |
| X117_ttn_78  | 156.300  | 6.500   | 1.420  | 0.065 | 0.933  | 0.704 |
| X117_ttn_79  | 615.000  | 29.000  | 5.380  | 0.260 | 0.935  | 0.186 |
| X117_ttn_80  | 1350.000 | 140.000 | 11.900 | 1.200 | 0.966  | 0.084 |
| X117_ttn_81  | 709.000  | 34.000  | 6.220  | 0.260 | 0.501  | 0.161 |
| X117_ttn_82  | 452.000  | 15.000  | 4.000  | 0.130 | 0.968  | 0.250 |
| X117_ttn_83  | 1103.000 | 62.000  | 9.830  | 0.580 | 0.993  | 0.102 |
| X117_ttn_84  | 196.000  | 7.600   | 1.757  | 0.078 | 0.985  | 0.569 |
| X117_ttn_85  | 421.000  | 16.000  | 3.800  | 0.140 | 0.812  | 0.263 |
| X117_ttn_86  | 101.600  | 5.100   | 0.928  | 0.048 | 0.632  | 1.078 |
| X117_ttn_87  | 118.800  | 6.700   | 1.097  | 0.061 | 0.861  | 0.912 |
| X117_ttn_88  | 206.000  | 11.000  | 1.870  | 0.110 | 0.499  | 0.535 |
| X117_ttn_89  | 218.000  | 16.000  | 1.920  | 0.130 | 0.947  | 0.521 |
| X117_ttn_90  | 111.500  | 4.500   | 1.021  | 0.037 | 0.858  | 0.979 |
| X117_ttn_91  | 581.000  | 43.000  | 4.980  | 0.400 | 0.976  | 0.201 |
| X117_ttn_92  | 311.000  | 13.000  | 2.710  | 0.110 | 0.876  | 0.369 |
| X117_ttn_93  | 226.600  | 6.300   | 2.043  | 0.061 | 0.861  | 0.489 |
| X117_ttn_94  | 23.570   | 0.820   | 0.258  | 0.009 | 0.990  | 3.880 |
| X117_ttn_95  | 103.200  | 8.100   | 0.951  | 0.071 | 0.987  | 1.052 |
| X117_ttn_96  | 163.000  | 12.000  | 1.510  | 0.110 | 0.979  | 0.662 |
| X117_ttn_97  | 198.600  | 7.800   | 1.816  | 0.073 | 0.978  | 0.551 |
| X117_ttn_98  | 135.100  | 7.000   | 1.238  | 0.061 | 0.966  | 0.808 |
| X117_ttn_99  | 192.500  | 6.000   | 1.729  | 0.050 | 0.789  | 0.578 |
| X117_ttn_100 | 52.200   | 1.400   | 0.501  | 0.011 | 0.805  | 1.996 |
| X117_ttn_101 | 661.000  | 17.000  | 5.830  | 0.180 | 0.205  | 0.172 |
| X117_ttn_102 | 182.600  | 5.100   | 1.618  | 0.055 | 0.505  | 0.618 |
| X117_ttn_103 | 689.000  | 30.000  | 6.010  | 0.260 | 0.965  | 0.166 |
| X117_ttn_104 | 163.500  | 9.900   | 1.484  | 0.092 | 0.708  | 0.674 |
| X117_ttn_105 | 155.000  | 13.000  | 1.390  | 0.110 | 0.605  | 0.719 |
| X117_ttn_106 | 222.400  | 7.500   | 2.044  | 0.088 | 0.655  | 0.489 |
| X117_ttn_107 | 279.000  | 19.000  | 2.480  | 0.170 | 0.977  | 0.403 |
| X117_ttn_108 | 176.700  | 9.100   | 1.509  | 0.064 | 0.139  | 0.663 |
| X117_ttn_109 | 529.000  | 52.000  | 4.520  | 0.400 | 0.965  | 0.221 |
| X117_ttn_110 | 396.000  | 15.000  | 3.530  | 0.150 | 0.986  | 0.283 |
| X117_ttn_111 | 161.900  | 5.900   | 1.466  | 0.058 | 0.160  | 0.682 |

|              |         |        |       |       |       |       |
|--------------|---------|--------|-------|-------|-------|-------|
| X117_ttn_112 | 391.000 | 14.000 | 3.440 | 0.110 | 0.717 | 0.291 |
| X117_ttn_113 | 256.000 | 11.000 | 2.248 | 0.085 | 0.964 | 0.445 |
| X117_ttn_114 | 313.000 | 13.000 | 2.760 | 0.110 | 0.715 | 0.362 |
| X117_ttn_115 | 192.100 | 8.400  | 1.732 | 0.096 | 0.909 | 0.577 |
| X117_ttn_116 | 78.000  | 4.300  | 0.710 | 0.033 | 0.081 | 1.408 |

| Error 2σ | <sup>207</sup> Pb/ <sup>206</sup> Pb | Error 2σ | rCorrelation_38_6v | FinalAge <sup>206</sup> Pb/ <sup>238</sup> U | Error 2σ |
|----------|--------------------------------------|----------|--------------------|----------------------------------------------|----------|
| 0.081    | 0.100                                | 0.004    | 0.061              | 1547.904                                     | 34.220   |
| 0.072    | 0.096                                | 0.002    | 0.030              | 1497.512                                     | 28.060   |
| 0.084    | 0.101                                | 0.013    | 0.001              | 1539.279                                     | 34.815   |
| 0.076    | 0.095                                | 0.001    | 0.195              | 1507.214                                     | 30.327   |
| 0.080    | 0.094                                | 0.002    | 0.666              | 1533.692                                     | 33.118   |
| 0.072    | 0.096                                | 0.002    | 0.430              | 1478.064                                     | 27.531   |
| 0.071    | 0.096                                | 0.002    | 0.134              | 1504.662                                     | 28.044   |
| 0.089    | 0.096                                | 0.002    | -0.290             | 1523.521                                     | 36.002   |
| 0.065    | 0.095                                | 0.002    | 0.000              | 1492.911                                     | 25.206   |
| 0.078    | 0.098                                | 0.003    | -0.198             | 1516.391                                     | 31.449   |
| 0.070    | 0.095                                | 0.002    | 0.009              | 1488.819                                     | 26.934   |
| 0.084    | 0.096                                | 0.003    | -0.012             | 1549.932                                     | 35.355   |
| 0.071    | 0.096                                | 0.001    | 0.096              | 1556.518                                     | 30.207   |
| 0.073    | 0.097                                | 0.003    | 0.201              | 1551.959                                     | 30.788   |
| 0.082    | 0.095                                | 0.002    | -0.254             | 1596.900                                     | 36.926   |
| 0.075    | 0.095                                | 0.002    | 0.094              | 1534.708                                     | 30.831   |
| 0.083    | 0.096                                | 0.002    | -0.201             | 1561.074                                     | 35.324   |
| 0.097    | 0.095                                | 0.002    | 0.454              | 1515.372                                     | 38.885   |
| 0.088    | 0.098                                | 0.003    | -0.579             | 1515.372                                     | 35.454   |
| 0.086    | 0.099                                | 0.004    | 0.011              | 1532.167                                     | 35.406   |
| 0.085    | 0.095                                | 0.003    | -0.246             | 1473.449                                     | 32.131   |
| 0.071    | 0.094                                | 0.002    | 0.128              | 1586.828                                     | 31.270   |
| 0.091    | 0.096                                | 0.002    | 0.650              | 1560.062                                     | 38.745   |
| 0.100    | 0.104                                | 0.009    | 0.147              | 1535.724                                     | 41.105   |
| 0.097    | 0.097                                | 0.004    | -0.249             | 1512.314                                     | 38.895   |
| 0.095    | 0.123                                | 0.028    | -0.302             | 1548.918                                     | 39.921   |
| 0.081    | 0.101                                | 0.004    | -0.350             | 1482.675                                     | 30.961   |
| 0.080    | 0.098                                | 0.003    | 0.196              | 1529.117                                     | 32.559   |
| 0.077    | 0.095                                | 0.002    | 0.550              | 1574.721                                     | 33.577   |
| 0.099    | 0.095                                | 0.002    | -0.059             | 1483.700                                     | 37.838   |
| 0.098    | 0.102                                | 0.005    | -0.192             | 1617.498                                     | 45.372   |
| 0.100    | 0.096                                | 0.002    | 0.358              | 1578.759                                     | 43.807   |
| 0.074    | 0.096                                | 0.002    | 0.198              | 1502.109                                     | 29.195   |
| 0.151    | 0.100                                | 0.007    | 0.248              | 1601.427                                     | 68.146   |
| 0.096    | 0.101                                | 0.006    | -0.073             | 1562.086                                     | 41.018   |
| 0.076    | 0.096                                | 0.004    | -0.102             | 1549.425                                     | 31.935   |
| 0.022    | 0.840                                | 0.017    | 0.008              | 10003.602                                    | 806.742  |
| 0.030    | 0.829                                | 0.010    | 0.007              | 8740.275                                     | 758.704  |
| 0.103    | 0.811                                | 0.023    | -0.116             | 5425.091                                     | 739.785  |
| 0.012    | 0.846                                | 0.014    | -0.294             | 11834.175                                    | 718.584  |
| 0.111    | 0.809                                | 0.017    | -0.051             | 4265.312                                     | 445.630  |
| 0.056    | 0.820                                | 0.010    | -0.131             | 7334.943                                     | 864.970  |
| 0.196    | 0.722                                | 0.012    | 0.020              | 2214.922                                     | 178.274  |
| 0.008    | 0.846                                | 0.011    | 0.142              | 16484.946                                    | 1523.819 |
| 0.010    | 0.836                                | 0.017    | 0.167              | 13099.680                                    | 889.119  |
| 0.024    | 0.849                                | 0.016    | 0.484              | 7754.858                                     | 432.674  |
| 0.036    | 0.807                                | 0.019    | -0.111             | 6147.214                                     | 354.573  |
| 0.008    | 0.846                                | 0.012    | -0.153             | 17584.869                                    | 2090.509 |

|       |       |       |        |           |          |
|-------|-------|-------|--------|-----------|----------|
| 0.102 | 0.806 | 0.016 | 0.171  | 6233.578  | 1032.556 |
| 0.018 | 0.829 | 0.012 | 0.329  | 8167.269  | 384.342  |
| 0.003 | 0.836 | 0.013 | 0.277  | 16374.059 | 574.774  |
| 0.003 | 0.841 | 0.011 | 0.219  | 16994.012 | 655.633  |
| 0.006 | 0.842 | 0.011 | 0.340  | 17668.590 | 1584.080 |
| 0.006 | 0.850 | 0.011 | -0.149 | 19148.522 | 2277.122 |
| 0.004 | 0.851 | 0.017 | 0.353  | 16998.628 | 838.791  |
| 0.001 | 0.843 | 0.009 | 0.027  | 28150.930 | 1592.083 |
| 0.019 | 0.833 | 0.009 | 0.052  | 9048.464  | 530.529  |
| 0.066 | 0.804 | 0.015 | -0.001 | 5341.188  | 455.450  |
| 0.088 | 0.826 | 0.017 | 0.285  | 5723.715  | 720.468  |
| 0.135 | 0.765 | 0.022 | 0.073  | 2618.092  | 177.675  |
| 0.068 | 0.744 | 0.016 | 0.302  | 2413.011  | 74.410   |
| 0.031 | 0.808 | 0.010 | 0.450  | 4545.210  | 146.477  |
| 0.038 | 0.820 | 0.017 | 0.300  | 4432.761  | 165.836  |
| 0.006 | 0.848 | 0.018 | 0.070  | 24155.670 | 5542.968 |
| 0.003 | 0.848 | 0.011 | 0.107  | 17832.839 | 777.943  |
| 0.005 | 0.833 | 0.010 | -0.256 | 18264.067 | 1369.805 |
| 0.002 | 0.842 | 0.011 | 0.033  | 24874.277 | 2412.376 |
| 0.114 | 0.803 | 0.023 | -0.078 | 5141.062  | 716.377  |
| 0.007 | 0.844 | 0.010 | 0.306  | 15434.342 | 1053.750 |
| 0.000 | 0.859 | 0.019 | 0.341  | #VALUE!   | #VALUE!  |
| 0.009 | 0.844 | 0.017 | -0.148 | 14512.759 | 1143.947 |
| 0.005 | 0.847 | 0.007 | -0.253 | 22882.304 | 3655.753 |
| 1.005 | 0.480 | 0.060 | -0.706 | 719.042   | 85.310   |
| 0.047 | 0.805 | 0.017 | -0.027 | 5327.098  | 323.357  |
| 0.411 | 0.294 | 0.012 | 0.400  | 465.009   | 14.298   |
| 0.046 | 0.798 | 0.014 | 0.343  | 5483.179  | 335.288  |
| 0.039 | 0.826 | 0.012 | 0.182  | 8221.517  | 828.525  |
| 0.023 | 0.821 | 0.010 | -0.117 | 6929.911  | 308.794  |
| 0.020 | 0.834 | 0.012 | 0.092  | 14778.629 | 2656.832 |
| 0.035 | 0.822 | 0.011 | 0.085  | 7617.903  | 606.736  |
| 0.096 | 0.771 | 0.008 | -0.245 | 3363.517  | 220.961  |
| 0.050 | 0.807 | 0.016 | -0.193 | 7983.073  | 977.519  |
| 0.002 | 0.844 | 0.019 | 0.104  | 30359.582 | 6347.913 |
| 0.002 | 0.839 | 0.032 | 0.419  | 27797.844 | 3663.575 |
| 0.069 | 0.832 | 0.032 | -0.025 | 9095.806  | 1936.527 |
| 0.034 | 0.826 | 0.017 | -0.054 | 7578.233  | 575.134  |
| 0.059 | 0.812 | 0.011 | 0.120  | 6402.912  | 640.291  |
| 0.010 | 0.840 | 0.011 | 0.032  | 10336.308 | 390.541  |
| 0.016 | 0.822 | 0.022 | 0.066  | 12125.644 | 1068.627 |
| 0.001 | 0.834 | 0.034 | -0.180 | 38377.072 | 7495.522 |
| 0.721 | 0.306 | 0.018 | -0.694 | 495.526   | 28.528   |
| 0.383 | 0.217 | 0.007 | 0.407  | 415.639   | 10.609   |
| 0.199 | 0.479 | 0.009 | 0.001  | 709.810   | 16.465   |
| 0.238 | 0.708 | 0.013 | -0.387 | 1872.221  | 150.000  |
| 0.386 | 0.410 | 0.015 | -0.474 | 631.966   | 25.156   |
| 0.543 | 0.407 | 0.023 | -0.636 | 573.255   | 28.971   |
| 0.770 | 0.479 | 0.046 | -0.309 | 675.651   | 57.476   |

|       |       |       |        |           |          |
|-------|-------|-------|--------|-----------|----------|
| 0.240 | 0.602 | 0.014 | -0.463 | 1087.701  | 47.935   |
| 0.076 | 0.808 | 0.024 | 0.070  | 5082.723  | 465.916  |
| 0.349 | 0.423 | 0.008 | 0.126  | 655.302   | 24.497   |
| 0.505 | 0.282 | 0.010 | -0.149 | 454.805   | 16.799   |
| 0.234 | 0.455 | 0.014 | 0.201  | 702.299   | 18.915   |
| 0.781 | 0.369 | 0.018 | -0.599 | 533.024   | 35.865   |
| 0.079 | 0.783 | 0.016 | -0.216 | 3465.994  | 194.719  |
| 0.064 | 0.798 | 0.017 | -0.107 | 4458.637  | 286.211  |
| 0.067 | 0.823 | 0.016 | 0.351  | 5480.425  | 490.784  |
| 0.416 | 0.645 | 0.022 | 0.680  | 1218.154  | 105.417  |
| 0.222 | 0.632 | 0.015 | 0.240  | 1194.631  | 53.981   |
| 0.150 | 0.748 | 0.013 | -0.237 | 2837.638  | 236.042  |
| 0.021 | 0.819 | 0.010 | -0.010 | 6069.741  | 201.807  |
| 0.011 | 0.838 | 0.012 | 0.052  | 10058.003 | 428.000  |
| 0.013 | 0.829 | 0.011 | 0.315  | 7094.990  | 180.381  |
| 0.037 | 0.819 | 0.014 | 0.246  | 5924.814  | 326.317  |
| 0.015 | 0.833 | 0.014 | -0.048 | 6639.655  | 176.959  |
| 0.036 | 0.828 | 0.012 | 0.341  | 8920.491  | 954.701  |
| 0.023 | 0.828 | 0.011 | -0.004 | 7103.562  | 328.672  |
| 0.012 | 0.839 | 0.011 | 0.121  | 9016.708  | 325.193  |
| 0.027 | 0.832 | 0.030 | -0.682 | 6504.768  | 306.019  |
| 0.021 | 0.833 | 0.013 | 0.274  | 7457.735  | 342.098  |
| 0.124 | 0.812 | 0.019 | 0.457  | 5452.817  | 901.970  |
| 0.109 | 0.788 | 0.037 | 0.002  | 3305.873  | 241.773  |
| 0.023 | 0.835 | 0.013 | 0.108  | 6648.854  | 272.585  |
| 0.009 | 0.828 | 0.018 | 0.126  | 14836.968 | 1188.278 |
| 0.046 | 0.797 | 0.020 | 0.021  | 3336.681  | 103.349  |
| 0.009 | 0.843 | 0.014 | 0.075  | 10218.503 | 368.709  |
| 0.034 | 0.825 | 0.027 | -0.014 | 4733.532  | 174.669  |
| 0.077 | 0.800 | 0.015 | -0.222 | 6951.875  | 1039.198 |
| 0.041 | 0.808 | 0.017 | 0.294  | 3990.087  | 139.676  |
| 0.026 | 0.829 | 0.015 | 0.043  | 8756.868  | 666.613  |
| 0.046 | 0.816 | 0.016 | 0.367  | 6009.116  | 429.223  |
| 0.035 | 0.829 | 0.034 | 0.199  | 10895.058 | 1676.163 |
| 0.009 | 0.821 | 0.012 | -0.221 | 13191.953 | 782.905  |
| 0.014 | 0.829 | 0.017 | 0.673  | 9235.782  | 405.332  |
| 0.198 | 0.718 | 0.016 | -0.060 | 1656.503  | 96.111   |
| 0.119 | 0.828 | 0.025 | -0.094 | 6134.781  | 1157.506 |
| 0.253 | 0.713 | 0.022 | -0.402 | 1852.906  | 155.800  |
| 0.173 | 0.737 | 0.019 | 0.377  | 2178.242  | 151.718  |
| 0.132 | 0.817 | 0.015 | -0.024 | 5082.723  | 804.764  |
| 0.044 | 0.811 | 0.029 | 0.094  | 5906.790  | 393.786  |
| 0.142 | 0.708 | 0.033 | 0.101  | 2136.726  | 119.613  |
| 0.142 | 0.794 | 0.019 | 0.232  | 6134.781  | 1389.007 |
| 0.227 | 0.758 | 0.043 | 0.065  | 2417.443  | 249.714  |
| 0.150 | 0.736 | 0.039 | -0.049 | 2791.815  | 226.642  |
| 0.129 | 0.768 | 0.035 | 0.207  | 2960.978  | 223.470  |
| 0.097 | 0.812 | 0.024 | 0.210  | 4813.460  | 520.374  |
| 0.208 | 0.776 | 0.027 | -0.419 | 4403.525  | 898.679  |



|       |       |       |        |           |          |
|-------|-------|-------|--------|-----------|----------|
| 0.061 | 0.792 | 0.022 | 0.271  | 4007.421  | 209.204  |
| 0.028 | 0.828 | 0.016 | 0.192  | 11047.851 | 1384.017 |
| 1.006 | 0.352 | 0.048 | 0.220  | 505.666   | 41.519   |
| 0.204 | 0.761 | 0.046 | -0.002 | 2260.479  | 193.755  |
| 0.252 | 0.741 | 0.038 | 0.215  | 1991.647  | 181.559  |
| 0.270 | 0.771 | 0.030 | 0.044  | 2770.878  | 402.474  |
| 0.100 | 0.783 | 0.029 | -0.010 | 3625.907  | 273.744  |
| 0.142 | 0.805 | 0.041 | -0.069 | 4069.439  | 508.680  |
| 0.118 | 0.728 | 0.031 | -0.078 | 2359.588  | 122.784  |
| 0.084 | 0.795 | 0.038 | 0.791  | 5697.132  | 682.051  |
| 0.043 | 0.784 | 0.035 | 0.090  | 5860.207  | 375.654  |
| 0.041 | 0.811 | 0.033 | -0.064 | 12164.833 | 2823.979 |
| 0.403 | 0.658 | 0.041 | -0.164 | 1621.509  | 187.097  |
| 0.062 | 0.808 | 0.032 | 0.367  | 8167.269  | 1281.140 |
| 0.046 | 0.850 | 0.030 | 0.108  | 8094.221  | 935.189  |
| 0.042 | 0.842 | 0.040 | -0.074 | 5554.381  | 316.929  |
| 0.095 | 0.817 | 0.022 | 0.321  | 4452.178  | 420.608  |
| 0.021 | 0.839 | 0.034 | 0.282  | 13795.753 | 2207.320 |
| 0.233 | 0.690 | 0.040 | -0.064 | 1365.869  | 75.239   |
| 0.028 | 0.837 | 0.046 | -0.215 | 9795.411  | 987.773  |
| 0.156 | 0.786 | 0.017 | -0.011 | 3789.116  | 473.640  |
| 0.156 | 0.777 | 0.027 | 0.323  | 5198.877  | 1006.234 |
| 0.023 | 0.822 | 0.021 | -0.049 | 14164.220 | 2655.791 |
| 0.032 | 0.820 | 0.033 | 0.011  | 5657.050  | 253.661  |
| 0.313 | 0.596 | 0.017 | -0.058 | 961.221   | 48.420   |
| 0.121 | 0.767 | 0.036 | 0.090  | 3870.965  | 385.685  |
| 0.267 | 0.777 | 0.034 | 0.464  | 3607.515  | 721.503  |
| 0.158 | 0.806 | 0.033 | -0.114 | 3702.586  | 453.280  |
| 0.524 | 0.235 | 0.021 | -0.324 | 404.751   | 13.742   |
| 0.675 | 0.543 | 0.045 | -0.185 | 867.242   | 84.315   |
| 0.034 | 0.842 | 0.028 | 0.502  | 6660.335  | 404.772  |
| 0.136 | 0.798 | 0.045 | 0.380  | 4271.961  | 545.357  |
| 0.412 | 0.805 | 0.027 | 0.037  | 5480.425  | 3026.503 |
| 0.033 | 0.790 | 0.030 | -0.011 | 5705.118  | 268.618  |
| 0.094 | 0.798 | 0.019 | 0.022  | 5802.813  | 794.906  |
| 0.051 | 0.797 | 0.024 | -0.171 | 5070.991  | 309.517  |
| 0.108 | 0.827 | 0.049 | -0.137 | 6258.043  | 1106.605 |
| 0.076 | 0.805 | 0.037 | 0.061  | 10111.948 | 2927.143 |
| 0.067 | 0.801 | 0.019 | 0.023  | 6354.983  | 718.718  |
| 0.128 | 0.775 | 0.013 | -0.486 | 3774.775  | 384.117  |
| 0.015 | 0.801 | 0.011 | -0.154 | 7349.390  | 228.049  |
| 0.014 | 0.820 | 0.010 | 0.087  | 10464.727 | 591.373  |
| 0.012 | 0.814 | 0.013 | 0.620  | 8690.238  | 304.921  |
| 0.021 | 0.837 | 0.017 | -0.013 | 10738.554 | 976.232  |
| 0.009 | 0.828 | 0.011 | -0.006 | 12203.784 | 649.137  |
| 0.007 | 0.824 | 0.008 | 0.224  | 12902.369 | 604.799  |
| 0.026 | 0.799 | 0.017 | -0.239 | 5181.587  | 167.961  |
| 0.012 | 0.796 | 0.008 | 0.661  | 7764.530  | 226.119  |
| 0.008 | 0.810 | 0.012 | 0.566  | 9574.436  | 255.057  |

|       |       |       |        |           |          |
|-------|-------|-------|--------|-----------|----------|
| 0.021 | 0.805 | 0.012 | -0.107 | 8203.485  | 446.882  |
| 0.011 | 0.814 | 0.009 | 0.203  | 14465.084 | 1355.565 |
| 0.028 | 0.791 | 0.013 | -0.172 | 6683.235  | 337.834  |
| 0.027 | 0.815 | 0.013 | 0.025  | 9506.933  | 874.525  |
| 0.008 | 0.813 | 0.009 | 0.709  | 12928.450 | 663.513  |
| 0.031 | 0.823 | 0.013 | 0.227  | 12544.143 | 2299.760 |
| 0.023 | 0.813 | 0.012 | 0.152  | 7983.073  | 456.176  |
| 0.022 | 0.811 | 0.009 | 0.445  | 7793.459  | 397.964  |
| 0.012 | 0.839 | 0.016 | -0.295 | 11059.456 | 582.077  |
| 0.015 | 0.800 | 0.011 | 0.311  | 8468.807  | 342.489  |
| 0.004 | 0.813 | 0.009 | 0.133  | 15783.501 | 627.159  |
| 0.019 | 0.831 | 0.010 | 0.058  | 9781.290  | 659.413  |
| 0.022 | 0.795 | 0.011 | -0.244 | 7192.890  | 329.499  |
| 0.021 | 0.805 | 0.013 | -0.206 | 7850.931  | 395.845  |
| 0.031 | 0.806 | 0.009 | -0.157 | 7754.858  | 565.805  |
| 0.042 | 0.808 | 0.010 | -0.099 | 8075.829  | 839.886  |
| 0.042 | 0.782 | 0.024 | 0.314  | 5088.580  | 254.006  |
| 0.005 | 0.827 | 0.006 | 0.157  | 13116.555 | 473.379  |
| 0.009 | 0.825 | 0.012 | 0.148  | 15733.160 | 1426.193 |
| 0.023 | 0.828 | 0.013 | 0.156  | 9638.348  | 779.982  |
| 0.074 | 0.759 | 0.022 | 0.460  | 3005.619  | 131.559  |
| 0.019 | 0.814 | 0.014 | 0.541  | 8257.430  | 412.872  |
| 0.019 | 0.802 | 0.011 | 0.309  | 7131.344  | 278.485  |
| 0.016 | 0.822 | 0.008 | 0.080  | 8673.472  | 397.025  |
| 0.016 | 0.835 | 0.011 | 0.097  | 14092.192 | 1783.822 |
| 0.019 | 0.825 | 0.017 | 0.672  | 8399.115  | 438.760  |
| 0.035 | 0.818 | 0.012 | -0.030 | 8806.393  | 904.766  |
| 0.023 | 0.834 | 0.013 | -0.012 | 11678.080 | 1345.716 |
| 0.018 | 0.813 | 0.012 | -0.167 | 8706.960  | 456.659  |
| 0.052 | 0.798 | 0.021 | 0.125  | 7578.233  | 879.616  |
| 0.028 | 0.834 | 0.012 | -0.082 | 9989.930  | 1050.154 |
| 0.009 | 0.816 | 0.017 | 0.299  | 13175.274 | 784.242  |
| 0.020 | 0.809 | 0.010 | 0.079  | 11365.138 | 1082.394 |
| 0.041 | 0.819 | 0.015 | -0.009 | 9095.806  | 1144.311 |
| 0.035 | 0.795 | 0.020 | -0.100 | 7518.266  | 578.328  |
| 0.019 | 0.823 | 0.010 | 0.051  | 9989.930  | 700.103  |
| 0.032 | 0.807 | 0.011 | 0.224  | 8328.662  | 694.055  |
| 0.046 | 0.786 | 0.010 | 0.224  | 5416.749  | 329.036  |
| 0.026 | 0.786 | 0.010 | -0.186 | 5201.755  | 167.663  |
| 0.026 | 0.822 | 0.012 | 0.219  | 7696.519  | 468.484  |
| 0.103 | 0.785 | 0.012 | -0.209 | 3976.187  | 349.606  |
| 0.015 | 0.827 | 0.014 | -0.038 | 8673.472  | 366.485  |
| 0.028 | 0.799 | 0.013 | 0.821  | 5103.201  | 173.348  |
| 0.034 | 0.773 | 0.013 | 0.136  | 3600.144  | 91.447   |
| 0.022 | 0.805 | 0.011 | 0.050  | 6816.716  | 275.716  |
| 0.023 | 0.811 | 0.006 | 0.195  | 8888.097  | 598.525  |
| 0.076 | 0.794 | 0.018 | 0.170  | 5397.244  | 535.604  |
| 0.045 | 0.789 | 0.014 | 0.397  | 4174.870  | 169.561  |
| 0.050 | 0.791 | 0.023 | -0.119 | 4347.938  | 207.690  |
| 0.042 | 0.795 | 0.014 | -0.411 | 4275.283  | 168.104  |

|       |       |       |        |           |          |
|-------|-------|-------|--------|-----------|----------|
| 0.013 | 0.793 | 0.010 | 0.318  | 7216.083  | 188.884  |
| 0.231 | 0.600 | 0.024 | 0.026  | 1014.315  | 39.882   |
| 0.080 | 0.706 | 0.016 | 0.393  | 2029.400  | 60.334   |
| 0.135 | 0.773 | 0.015 | -0.161 | 3537.143  | 348.392  |
| 0.029 | 0.797 | 0.013 | 0.597  | 6521.198  | 331.650  |
| 0.320 | 0.734 | 0.022 | -0.106 | 2319.227  | 321.371  |
| 0.032 | 0.821 | 0.023 | 0.091  | 6951.875  | 430.013  |
| 0.016 | 0.809 | 0.011 | -0.463 | 12006.630 | 1015.267 |
| 0.011 | 0.818 | 0.011 | 0.438  | 7904.114  | 213.359  |
| 0.027 | 0.805 | 0.014 | 0.408  | 7457.735  | 444.727  |
| 0.011 | 0.815 | 0.009 | 0.425  | 9432.750  | 340.943  |
| 0.011 | 0.811 | 0.013 | 0.413  | 10071.531 | 400.724  |
| 0.006 | 0.819 | 0.021 | -0.075 | 15997.214 | 1094.700 |
| 0.027 | 0.823 | 0.013 | 0.741  | 8203.485  | 574.563  |
| 0.045 | 0.801 | 0.019 | -0.310 | 6567.912  | 519.496  |
| 0.012 | 0.789 | 0.011 | 0.089  | 9921.131  | 433.711  |
| 0.032 | 0.803 | 0.015 | 0.472  | 5697.132  | 260.784  |
| 0.009 | 0.827 | 0.013 | 0.275  | 11946.289 | 577.330  |
| 0.008 | 0.816 | 0.010 | -0.042 | 16484.946 | 1662.348 |
| 0.007 | 0.812 | 0.016 | 0.048  | 12743.626 | 532.692  |
| 0.008 | 0.816 | 0.009 | 0.292  | 10375.103 | 337.191  |
| 0.006 | 0.815 | 0.008 | 0.125  | 15357.422 | 906.135  |
| 0.025 | 0.810 | 0.011 | 0.431  | 6537.587  | 290.229  |
| 0.010 | 0.812 | 0.015 | 0.155  | 10111.948 | 372.545  |
| 0.056 | 0.779 | 0.018 | 0.670  | 4231.963  | 218.895  |
| 0.051 | 0.786 | 0.013 | -0.327 | 4773.620  | 265.443  |
| 0.031 | 0.805 | 0.010 | 0.542  | 6796.532  | 399.796  |
| 0.035 | 0.814 | 0.014 | -0.168 | 6907.872  | 467.720  |
| 0.035 | 0.797 | 0.011 | 0.153  | 4535.648  | 164.367  |
| 0.016 | 0.840 | 0.014 | 0.495  | 11528.900 | 926.016  |
| 0.015 | 0.829 | 0.013 | 0.035  | 8451.454  | 343.048  |
| 0.015 | 0.811 | 0.012 | 0.305  | 7173.853  | 214.197  |
| 0.130 | 0.664 | 0.010 | -0.559 | 1478.064  | 49.326   |
| 0.079 | 0.786 | 0.010 | -0.163 | 4308.410  | 321.658  |
| 0.048 | 0.783 | 0.010 | -0.029 | 5932.524  | 432.171  |
| 0.022 | 0.799 | 0.012 | 0.052  | 6674.085  | 268.286  |
| 0.040 | 0.790 | 0.010 | -0.022 | 5193.119  | 255.881  |
| 0.017 | 0.811 | 0.013 | 0.205  | 6471.782  | 187.154  |
| 0.044 | 0.748 | 0.010 | 0.116  | 2618.092  | 57.483   |
| 0.005 | 0.835 | 0.013 | 0.632  | 12385.655 | 382.404  |
| 0.021 | 0.818 | 0.018 | 0.638  | 6204.098  | 210.893  |
| 0.007 | 0.831 | 0.011 | 0.203  | 12553.345 | 543.073  |
| 0.042 | 0.790 | 0.010 | -0.045 | 5865.400  | 363.623  |
| 0.057 | 0.798 | 0.019 | 0.020  | 5616.718  | 444.488  |
| 0.021 | 0.811 | 0.024 | 0.614  | 7175.971  | 308.946  |
| 0.028 | 0.815 | 0.012 | 0.110  | 8038.887  | 551.053  |
| 0.028 | 0.811 | 0.031 | 0.115  | 5929.955  | 251.502  |
| 0.020 | 0.813 | 0.017 | 0.000  | 11012.911 | 974.594  |
| 0.012 | 0.817 | 0.013 | 0.575  | 9738.739  | 413.827  |
| 0.027 | 0.799 | 0.021 | -0.134 | 5818.517  | 230.201  |

|       |       |       |       |          |         |
|-------|-------|-------|-------|----------|---------|
| 0.009 | 0.820 | 0.013 | 0.045 | 9609.376 | 307.277 |
| 0.017 | 0.820 | 0.014 | 0.030 | 7594.130 | 287.145 |
| 0.014 | 0.819 | 0.022 | 0.198 | 8537.753 | 340.273 |
| 0.032 | 0.817 | 0.026 | 0.338 | 6478.865 | 359.106 |
| 0.065 | 0.785 | 0.018 | 0.130 | 3458.458 | 160.745 |

| FinalAge $^{207}\text{Pb}/^{235}\text{U}$ | Error $2\sigma$ | alAge $^{207}\text{Pb}/^{201}\text{Pb}$ | Error $2\sigma$ | FinalAge $^{207}\text{Pb}$ corr | Error $2\sigma$ |
|-------------------------------------------|-----------------|-----------------------------------------|-----------------|---------------------------------|-----------------|
| 1599.072                                  | 83.502          | 1624.083                                | 60.091          | 1540.952                        | 33.594          |
| 1520.196                                  | 29.361          | 1543.853                                | 30.619          | 1493.591                        | 27.240          |
| 1599.072                                  | 229.632         | 1642.570                                | 211.420         | 1529.869                        | 40.345          |
| 1522.692                                  | 32.379          | 1522.114                                | 17.680          | 1505.951                        | 29.357          |
| 1516.326                                  | 29.870          | 1516.130                                | 30.515          | 1535.215                        | 32.245          |
| 1501.392                                  | 30.143          | 1541.890                                | 24.168          | 1472.768                        | 26.619          |
| 1526.538                                  | 34.922          | 1553.632                                | 35.493          | 1500.476                        | 27.291          |
| 1534.858                                  | 39.522          | 1537.955                                | 30.598          | 1522.270                        | 34.950          |
| 1504.396                                  | 48.672          | 1522.114                                | 36.968          | 1490.477                        | 24.619          |
| 1545.107                                  | 47.475          | 1582.592                                | 43.691          | 1510.617                        | 30.640          |
| 1501.855                                  | 41.657          | 1535.984                                | 32.201          | 1484.887                        | 26.165          |
| 1550.635                                  | 38.282          | 1555.580                                | 43.569          | 1549.426                        | 34.550          |
| 1553.937                                  | 35.200          | 1539.924                                | 22.551          | 1558.009                        | 29.394          |
| 1579.974                                  | 46.470          | 1565.283                                | 51.691          | 1550.758                        | 30.316          |
| 1567.039                                  | 46.841          | 1530.055                                | 30.569          | 1603.150                        | 36.149          |
| 1542.888                                  | 56.184          | 1528.074                                | 32.170          | 1535.288                        | 30.050          |
| 1560.509                                  | 47.029          | 1549.728                                | 29.027          | 1562.101                        | 34.394          |
| 1525.182                                  | 33.204          | 1526.090                                | 28.946          | 1514.456                        | 37.706          |
| 1542.888                                  | 69.149          | 1584.503                                | 50.173          | 1509.345                        | 34.549          |
| 1542.888                                  | 64.827          | 1607.248                                | 58.386          | 1525.450                        | 34.665          |
| 1497.449                                  | 62.209          | 1534.010                                | 41.851          | 1468.489                        | 31.216          |
| 1558.542                                  | 39.381          | 1510.122                                | 27.282          | 1593.877                        | 30.629          |
| 1560.509                                  | 51.304          | 1547.772                                | 33.858          | 1561.173                        | 37.747          |
| 1609.530                                  | 112.003         | 1693.150                                | 140.280         | 1521.170                        | 42.099          |
| 1560.509                                  | 102.609         | 1571.075                                | 63.037          | 1507.230                        | 38.059          |
| 1784.899                                  | 446.225         | 2000.193                                | 455.328         | 1501.864                        | 61.561          |
| 1571.369                                  | 110.421         | 1640.731                                | 56.913          | 1469.121                        | 30.187          |
| 1547.322                                  | 43.101          | 1580.679                                | 51.772          | 1524.559                        | 31.884          |
| 1567.473                                  | 37.888          | 1534.010                                | 25.755          | 1578.443                        | 32.758          |
| 1495.123                                  | 48.947          | 1524.103                                | 25.723          | 1480.364                        | 36.563          |
| 1642.287                                  | 117.887         | 1660.831                                | 83.042          | 1613.173                        | 44.936          |
| 1567.039                                  | 42.583          | 1545.814                                | 33.850          | 1581.796                        | 42.728          |
| 1515.413                                  | 41.753          | 1541.890                                | 32.223          | 1498.738                        | 28.355          |
| 1650.314                                  | 133.481         | 1625.942                                | 113.702         | 1599.049                        | 67.252          |
| 1632.163                                  | 134.991         | 1649.901                                | 92.746          | 1553.855                        | 40.778          |
| 1547.322                                  | 64.651          | 1545.814                                | 59.640          | 1549.748                        | 31.601          |
|                                           |                 |                                         |                 |                                 |                 |
| 6157.065                                  | 516.677         | 4991.118                                | 101.011         | -401.040                        | 610.286         |
| 5888.300                                  | 501.132         | 4972.394                                | 59.981          | 154.398                         | 300.827         |
| 5121.008                                  | 831.333         | 4941.178                                | 140.132         | 748.550                         | 250.532         |
| 6498.713                                  | 410.900         | 5001.222                                | 82.763          | -9194.813                       | 3356.044        |
| 4725.552                                  | 499.818         | 4937.664                                | 103.758         | 384.788                         | 139.866         |
| 5556.451                                  | 656.458         | 4957.224                                | 59.835          | 2392.282                        | 349.571         |
| 3792.746                                  | 324.563         | 4775.137                                | 79.365          | 454.768                         | 55.969          |
| 7326.979                                  | 646.498         | 5001.222                                | 65.028          | -1074.208                       | 1543.692        |
| 6734.022                                  | 453.081         | 4984.340                                | 101.356         | -343.904                        | 1074.347        |
| 5680.775                                  | 296.757         | 5006.245                                | 94.346          | -141.388                        | 347.474         |
| 5284.060                                  | 379.518         | 4934.141                                | 116.169         | 1385.289                        | 229.824         |
| 7553.406                                  | 933.068         | 5001.222                                | 70.939          | 0.000                           | 2202.335        |

|           |          |          |         |           |            |
|-----------|----------|----------|---------|-----------|------------|
| 5284.060  | 846.617  | 4932.376 | 97.913  | 1511.353  | 307.697    |
| 5753.594  | 239.733  | 4972.394 | 71.977  | 0.000     | 317.777    |
| 7326.232  | 253.372  | 4984.340 | 77.508  | 0.000     | 1650.374   |
| 7424.365  | 267.813  | 4992.807 | 65.304  | -588.624  | 1570.171   |
| 7529.243  | 589.640  | 4994.495 | 65.249  | -790.532  | 1805.057   |
| 7777.472  | 917.155  | 5007.915 | 64.808  | 0.000     | 3649.522   |
| 7439.169  | 288.947  | 5009.583 | 100.074 | -1819.880 | 2556.074   |
| 9246.283  | 523.374  | 4996.011 | 53.345  | 0.000     | 14678.327  |
| 5948.046  | 340.862  | 4979.404 | 55.586  | 62.943    | 310.882    |
| 5039.188  | 461.334  | 4928.839 | 91.956  | 869.468   | 169.742    |
| 5244.236  | 723.343  | 4967.242 | 102.231 | 464.039   | 210.263    |
| 4035.192  | 286.019  | 4857.929 | 139.705 | 371.889   | 92.303     |
| 3920.120  | 126.455  | 4818.134 | 103.616 | 420.276   | 61.774     |
| 4814.386  | 144.093  | 4935.904 | 61.088  | 470.880   | 99.522     |
| 4792.895  | 168.096  | 4956.877 | 102.765 | 264.286   | 145.243    |
| 8507.043  | 1760.078 | 5004.573 | 106.229 | #VALUE!   | #VALUE!    |
| 7586.873  | 310.902  | 5004.573 | 64.918  | 0.000     | 1908.918   |
| 7639.215  | 619.396  | 4978.380 | 58.006  | 0.000     | 1664.220   |
| 8724.665  | 825.525  | 4994.495 | 65.249  | 0.000     | 8419.178   |
| 5010.381  | 689.835  | 4927.067 | 141.124 | 785.949   | 236.327    |
| 7164.721  | 469.818  | 4997.526 | 56.857  | 0.000     | 1993.199   |
| #VALUE!   | #VALUE!  | 5022.854 | 111.099 | 0.000     | #####      |
| 7065.491  | 645.373  | 4997.862 | 100.668 | #VALUE!   | #VALUE!    |
| 8441.994  | 1386.308 | 5002.898 | 40.756  | 0.000     | 10115.893  |
| 2231.025  | 474.093  | 4180.933 | 522.617 | 348.264   | 67.881     |
| 5052.591  | 330.051  | 4930.609 | 104.125 | 839.021   | 177.243    |
| 1420.233  | 74.504   | 3438.894 | 140.363 | 329.210   | 12.206     |
| 5101.163  | 337.825  | 4918.171 | 86.284  | 1098.240  | 160.127    |
| 5774.458  | 569.589  | 4967.242 | 72.163  | #NUM!     | #VALUE!    |
| 5481.203  | 274.060  | 4958.610 | 60.397  | 1627.507  | 176.120    |
| 7035.120  | 1310.464 | 4980.938 | 71.668  | 3385.691  | 4883.850   |
| 5634.438  | 440.190  | 4960.341 | 66.379  | 2969.523  | 401.525    |
| 4343.864  | 262.709  | 4868.901 | 48.632  | 524.547   | 64.606     |
| 5703.174  | 749.322  | 4934.141 | 97.827  | #VALUE!   | #VALUE!    |
| 9602.760  | 1875.539 | 4997.862 | 112.511 | 0.000     | 18707.297  |
| 9150.644  | 1115.932 | 4989.427 | 190.300 | 0.000     | 25304.139  |
| 5968.153  | 1274.100 | 4977.527 | 191.443 | #VALUE!   | #VALUE!    |
| 5642.309  | 481.127  | 4967.242 | 102.231 | 2371.912  | 341.172    |
| 5316.994  | 540.229  | 4942.932 | 66.961  | 1452.917  | 206.668    |
| 6225.543  | 244.139  | 4991.118 | 65.360  | -448.218  | 478.129    |
| 6541.646  | 563.395  | 4960.341 | 132.759 | 0.000     | 1106.807   |
| 10923.414 | 2324.131 | 4980.938 | 203.060 | 0.000     | 109771.265 |
| 1509.001  | 154.430  | 3500.863 | 205.933 | 344.120   | 22.446     |
| 1114.158  | 24.002   | 2954.841 | 96.902  | 333.391   | 9.170      |
| 2195.434  | 68.518   | 4177.848 | 80.243  | 344.383   | 12.061     |
| 3580.607  | 325.510  | 4747.041 | 87.163  | 403.295   | 49.259     |
| 1955.331  | 116.786  | 3946.162 | 144.372 | 360.241   | 18.627     |
| 1849.336  | 174.937  | 3935.141 | 222.379 | 327.230   | 23.293     |
| 2231.025  | 362.541  | 4177.848 | 401.213 | 326.647   | 47.855     |

|          |          |          |         |         |          |          |
|----------|----------|----------|---------|---------|----------|----------|
| 2852.620 | 179.203  | 4512.833 | 104.950 |         | 368.837  | 26.604   |
| 5003.050 | 474.742  | 4935.904 | 146.611 |         | 657.971  | 228.086  |
| 2012.875 | 77.171   | 3993.978 | 77.370  |         | 363.191  | 15.274   |
| 1379.306 | 62.045   | 3374.039 | 119.647 |         | 328.581  | 13.270   |
| 2147.586 | 88.378   | 4101.635 | 126.204 |         | 362.310  | 16.052   |
| 1712.341 | 167.342  | 3787.319 | 184.747 |         | 328.895  | 24.929   |
| 4425.029 | 269.749  | 4891.124 | 99.946  |         | 457.887  | 98.393   |
| 4762.583 | 317.800  | 4918.171 | 104.773 |         | 589.581  | 142.139  |
| 5053.291 | 421.108  | 4962.070 | 96.468  |         | 462.836  | 185.064  |
| 3000.366 | 214.312  | 4612.796 | 157.336 |         | 346.440  | 46.896   |
| 2980.068 | 130.441  | 4583.348 | 108.782 |         | 360.615  | 29.887   |
| 4131.621 | 366.457  | 4825.806 | 83.871  |         | 518.098  | 74.497   |
| 5250.599 | 179.918  | 4955.142 | 60.502  |         | 883.739  | 144.238  |
| 6164.124 | 271.107  | 4987.733 | 71.423  | #VALUE! |          | #VALUE!  |
| 5498.965 | 139.992  | 4972.394 | 65.979  |         | 1293.145 | 187.114  |
| 5217.785 | 301.677  | 4955.142 | 84.703  |         | 791.461  | 178.586  |
| 5414.262 | 184.069  | 4979.233 | 83.685  |         | 619.729  | 214.629  |
| 5857.055 | 532.460  | 4970.679 | 72.039  |         | 184.230  | 349.723  |
| 5552.176 | 282.314  | 4970.679 | 66.036  |         | 1377.853 | 193.198  |
| 5965.305 | 218.448  | 4989.427 | 65.416  |         | -84.562  | 347.716  |
| 5384.886 | 296.169  | 4977.527 | 179.478 |         | 591.252  | 398.830  |
| 5581.731 | 252.671  | 4979.233 | 77.707  |         | 1435.972 | 231.504  |
| 4961.753 | 369.773  | 4942.932 | 115.660 |         | 737.620  | 229.594  |
| 4398.688 | 363.141  | 4900.201 | 230.086 |         | 381.037  | 194.833  |
| 5420.622 | 219.755  | 4982.640 | 77.574  |         | 508.575  | 208.014  |
| 7034.125 | 572.946  | 4970.679 | 108.058 |         | 544.492  | 1382.989 |
| 4406.663 | 180.458  | 4916.385 | 123.372 |         | 318.017  | 112.720  |
| 6209.973 | 219.822  | 4996.180 | 82.973  |         | -741.349 | 576.880  |
| 4892.793 | 254.999  | 4965.520 | 162.508 |         | 233.166  | 239.043  |
| 5508.402 | 877.445  | 4921.737 | 92.283  |         | 3077.205 | 701.221  |
| 4640.888 | 169.907  | 4935.904 | 103.849 |         | 338.205  | 124.154  |
| 5891.373 | 464.169  | 4972.394 | 89.971  |         | 154.930  | 398.089  |
| 5199.760 | 306.052  | 4949.923 | 97.057  |         | 949.728  | 202.766  |
| 6371.287 | 1009.789 | 4972.394 | 203.934 | #VALUE! |          | #VALUE!  |
| 6751.266 | 446.582  | 4958.610 | 72.477  | #VALUE! |          | #VALUE!  |
| 5979.467 | 215.925  | 4972.394 | 101.967 | #VALUE! |          | #VALUE!  |
| 3473.625 | 246.440  | 4767.170 | 106.232 |         | 318.086  | 43.464   |
| 5333.069 | 1010.476 | 4970.679 | 150.081 |         | 573.257  | 325.480  |
| 3595.430 | 343.444  | 4757.143 | 146.784 |         | 382.988  | 66.532   |
| 3748.161 | 258.824  | 4804.602 | 123.864 |         | 388.497  | 67.636   |
| 5053.291 | 947.492  | 4951.665 | 90.912  |         | 472.564  | 169.855  |
| 5208.812 | 434.068  | 4941.178 | 176.688 |         | 1043.501 | 316.779  |
| 3737.982 | 202.836  | 4747.041 | 221.260 |         | 482.341  | 102.594  |
|          |          |          |         |         |          |          |
| 5184.491 | 1106.446 | 4911.012 | 117.518 |         | 1826.333 | 456.493  |
| 3970.169 | 503.375  | 4844.795 | 274.837 |         | 360.070  | 156.127  |
| 4098.095 | 353.792  | 4802.658 | 254.489 |         | 568.703  | 164.696  |
| 4229.186 | 380.226  | 4863.519 | 221.645 |         | 436.065  | 160.713  |
| 4910.679 | 510.711  | 4942.932 | 146.096 |         | 484.710  | 216.178  |
| 4791.084 | 992.747  | 4878.312 | 169.735 |         | 860.835  | 257.278  |



|          |          |          |         |           |          |
|----------|----------|----------|---------|-----------|----------|
| 4608.855 | 228.950  | 4907.418 | 136.317 | 520.849   | 151.930  |
| 6359.748 | 801.037  | 4970.679 | 96.052  | 2370.845  | 715.484  |
| 1662.236 | 357.341  | 3715.676 | 506.683 | 322.173   | 39.880   |
| 3874.206 | 392.656  | 4850.440 | 293.193 | 314.020   | 153.177  |
| 3693.543 | 329.424  | 4812.351 | 246.787 | 329.655   | 111.643  |
| 4140.262 | 642.455  | 4869.086 | 189.459 | 374.217   | 137.519  |
| 4502.596 | 389.180  | 4891.124 | 181.153 | 500.483   | 172.963  |
| 4696.119 | 650.947  | 4930.609 | 251.124 | 389.706   | 283.413  |
| 3880.894 | 243.098  | 4787.001 | 203.842 | 473.245   | 108.082  |
| 5124.931 | 281.772  | 4912.805 | 234.826 | 1340.170  | 395.381  |
| 5178.318 | 317.688  | 4892.944 | 218.435 | 1802.651  | 356.221  |
| 6513.781 | 1494.966 | 4941.178 | 201.059 | 1074.127  | 1455.540 |
| 3354.031 | 499.264  | 4641.615 | 289.219 | 458.049   | 103.077  |
| 5725.090 | 1001.891 | 4935.904 | 195.481 | 1243.817  | 629.212  |
| 5781.319 | 683.602  | 5007.915 | 176.750 | -78.036   | 636.027  |
| 5214.803 | 833.134  | 4994.495 | 237.268 | -79.174   | 460.571  |
| 4751.332 | 262.726  | 4951.665 | 133.337 | 312.718   | 182.080  |
| 6752.581 | 717.243  | 4989.427 | 202.194 | -6296.547 | 6039.846 |
| 3156.888 | 221.277  | 4710.033 | 273.045 | 306.919   | 75.734   |
| 6088.696 | 607.351  | 4986.038 | 274.024 | #VALUE!   | #VALUE!  |
| 4556.544 | 368.048  | 4896.577 | 105.906 | 519.000   | 127.968  |
| 4844.072 | 703.840  | 4880.150 | 169.581 | 1332.373  | 338.274  |
| 6885.371 | 1173.643 | 4960.341 | 126.724 | #VALUE!   | #VALUE!  |
| 5196.724 | 469.584  | 4956.877 | 199.484 | 618.875   | 349.911  |
| 2689.757 | 173.995  | 4498.277 | 128.307 | 328.440   | 27.526   |
| 4581.365 | 498.306  | 4861.659 | 228.187 | 729.881   | 228.332  |
| 4356.460 | 847.089  | 4880.150 | 213.546 | 547.493   | 220.887  |
| 4503.800 | 534.624  | 4932.376 | 201.946 | 305.360   | 206.632  |
| 1152.077 | 103.742  | 3086.418 | 275.808 | 315.161   | 14.895   |
| 2548.205 | 338.257  | 4362.409 | 361.526 | 354.526   | 60.321   |
| 5419.646 | 314.182  | 4994.495 | 166.088 | 83.010    | 421.849  |
| 4706.025 | 645.925  | 4918.171 | 277.340 | 529.096   | 325.320  |
| 4869.564 | 811.594  | 4930.609 | 165.374 | 926.873   | 559.754  |
| 5151.975 | 285.500  | 4903.814 | 186.221 | 1478.449  | 294.783  |
| 5255.775 | 806.284  | 4918.171 | 117.099 | 1350.722  | 266.628  |
| 4936.144 | 350.382  | 4916.385 | 148.047 | 868.544   | 218.268  |
| 5389.925 | 1072.622 | 4968.962 | 294.412 | 683.405   | 600.820  |
| 5939.305 | 652.294  | 4930.609 | 226.624 | #NUM!     | #VALUE!  |
| 5238.417 | 545.038  | 4923.516 | 116.788 | 1852.082  | 301.933  |
| 4546.212 | 522.553  | 4876.472 | 81.799  | 618.905   | 107.063  |
| 5548.312 | 176.998  | 4923.516 | 67.614  | 0.000     | 240.115  |
| 6249.539 | 345.719  | 4956.877 | 60.450  | 0.000     | 455.124  |
| 5852.285 | 167.735  | 4946.432 | 78.997  | #VALUE!   | #VALUE!  |
| 6336.270 | 631.152  | 4986.038 | 101.270 | -157.902  | 678.122  |
| 6562.451 | 358.884  | 4970.679 | 66.036  | #NUM!     | #VALUE!  |
| 6684.682 | 305.533  | 4964.486 | 49.380  | 0.000     | 693.909  |
| 4985.236 | 200.002  | 4919.955 | 104.680 | 888.694   | 164.368  |
| 5640.740 | 168.609  | 4915.133 | 51.849  | 1521.573  | 193.744  |
| 6031.282 | 141.669  | 4939.422 | 73.177  | 0.000     | 380.204  |

|          |          |          |         |           |          |
|----------|----------|----------|---------|-----------|----------|
| 5728.697 | 326.189  | 4930.609 | 73.500  | 1387.576  | 272.470  |
| 6942.512 | 633.849  | 4946.257 | 54.695  | #VALUE!   | #VALUE!  |
| 5389.925 | 294.971  | 4905.617 | 80.623  | 2922.426  | 278.614  |
| 6028.874 | 574.178  | 4948.178 | 78.928  | #VALUE!   | #VALUE!  |
| 6691.680 | 358.976  | 4944.683 | 55.346  | 0.000     | 666.599  |
| 6546.485 | 1143.037 | 4962.070 | 78.380  | #VALUE!   | #VALUE!  |
| 5703.174 | 333.032  | 4944.683 | 72.984  | 442.544   | 278.819  |
| 5661.724 | 279.857  | 4940.652 | 53.630  | #VALUE!   | #VALUE!  |
| 6351.983 | 415.322  | 4989.427 | 95.150  | -1227.326 | 813.690  |
| 5788.134 | 213.656  | 4921.737 | 67.674  | 1747.613  | 270.125  |
| 7169.088 | 289.473  | 4944.858 | 53.517  | #VALUE!   | #VALUE!  |
| 6121.012 | 428.767  | 4975.818 | 59.877  | 374.538   | 360.980  |
| 5499.417 | 245.510  | 4912.805 | 67.976  | 0.000     | 276.127  |
| 5657.871 | 302.329  | 4930.609 | 79.625  | 578.401   | 282.946  |
| 5654.003 | 433.257  | 4932.729 | 55.678  | 544.860   | 222.998  |
| 5735.873 | 628.311  | 4935.904 | 61.088  | 1207.253  | 259.149  |
| 4967.103 | 270.523  | 4889.301 | 150.055 | 1159.129  | 211.552  |
| 6727.311 | 232.284  | 4969.133 | 33.043  | 0.000     | 581.774  |
| 7174.304 | 613.188  | 4965.520 | 72.226  | 0.000     | 1299.774 |
| 6088.696 | 531.432  | 4970.679 | 78.042  | 582.401   | 407.668  |
| 4227.608 | 180.325  | 4846.679 | 140.483 | 502.842   | 105.131  |
| 5764.080 | 277.310  | 4946.432 | 85.074  | 448.747   | 329.889  |
| 5503.020 | 203.181  | 4925.292 | 67.554  | 0.000     | 238.677  |
| 5866.530 | 273.286  | 4960.514 | 47.065  | #VALUE!   | #VALUE!  |
| 6896.831 | 929.910  | 4982.640 | 65.640  | 845.538   | 822.089  |
| 5811.631 | 285.818  | 4965.520 | 102.320 | 229.619   | 404.045  |
| 5888.300 | 626.415  | 4953.404 | 72.666  | #VALUE!   | #VALUE!  |
| 6512.118 | 769.906  | 4980.938 | 77.641  | 702.973   | 599.135  |
| 5869.669 | 345.275  | 4944.683 | 72.984  | 1225.974  | 302.952  |
| 5602.328 | 655.111  | 4918.171 | 129.426 | 666.328   | 394.236  |
| 6154.701 | 661.487  | 4980.938 | 71.668  | 142.573   | 434.619  |
| 6688.887 | 387.494  | 4949.923 | 103.123 | #VALUE!   | #VALUE!  |
| 6443.252 | 713.400  | 4937.664 | 61.034  | 1003.917  | 478.158  |
| 5942.227 | 787.730  | 4955.142 | 90.754  | 1035.941  | 405.027  |
| 5598.242 | 430.634  | 4912.805 | 123.593 | #VALUE!   | #VALUE!  |
| 6137.996 | 422.807  | 4962.760 | 59.669  | 2273.580  | 392.191  |
| 5757.101 | 458.178  | 4934.141 | 67.256  | 1355.796  | 277.558  |
| 5043.440 | 321.846  | 4896.577 | 62.297  | 1322.297  | 134.454  |
| 4987.480 | 162.675  | 4896.577 | 62.297  | 1161.279  | 111.680  |
| 5646.222 | 348.801  | 4960.341 | 72.414  | 3299.381  | 520.199  |
| 4576.897 | 397.991  | 4894.762 | 74.824  | 586.516   | 102.741  |
| 5888.300 | 304.259  | 4968.962 | 84.118  | 197.817   | 369.502  |
| 4969.388 | 120.015  | 4919.955 | 80.049  | 846.700   | 132.374  |
| 4454.500 | 162.696  | 4872.784 | 81.949  | 579.496   | 84.224   |
| 5428.395 | 223.583  | 4930.609 | 67.375  | 2405.458  | 195.936  |
| 5897.489 | 408.561  | 4941.529 | 37.159  | 1397.566  | 232.257  |
| 5053.291 | 491.292  | 4911.012 | 111.333 | 1130.417  | 204.871  |
| 4662.725 | 181.355  | 4902.008 | 86.981  | 608.115   | 109.602  |
| 4763.515 | 291.104  | 4905.617 | 142.641 | 644.651   | 172.839  |
| 4715.836 | 192.296  | 4912.805 | 86.515  | 568.263   | 113.533  |

|          |         |          |         |         |          |          |
|----------|---------|----------|---------|---------|----------|----------|
| 5503.020 | 137.086 | 4908.857 | 59.441  |         | 697.601  | 197.661  |
| 2728.504 | 161.438 | 4507.998 | 180.320 |         | 343.417  | 34.886   |
| 3663.717 | 122.464 | 4742.979 | 107.490 |         | 456.016  | 50.279   |
| 4472.028 | 475.983 | 4872.784 | 94.556  |         | 559.815  | 105.564  |
| 5349.940 | 188.300 | 4916.385 | 80.192  |         | 2274.218 | 208.190  |
| 3913.686 | 626.867 | 4798.761 | 143.832 |         | 437.262  | 96.126   |
| 5476.598 | 350.102 | 4958.610 | 138.914 |         | 1658.009 | 323.135  |
| 6491.944 | 521.965 | 4937.664 | 67.138  | #VALUE! |          | #VALUE!  |
| 5693.901 | 132.124 | 4953.404 | 66.611  |         | 0.000    | 257.261  |
| 5573.374 | 323.764 | 4930.609 | 85.750  |         | 0.000    | 351.792  |
| 6020.804 | 208.721 | 4947.654 | 54.657  |         | 3106.476 | 495.533  |
| 6140.399 | 232.811 | 4941.178 | 79.205  | #VALUE! |          | #VALUE!  |
| 7199.990 | 779.999 | 4955.142 | 127.055 | #VALUE! |          | #VALUE!  |
| 5739.442 | 282.930 | 4962.070 | 78.380  |         | 261.252  | 314.885  |
| 5343.646 | 306.146 | 4923.516 | 116.788 |         | 2167.342 | 291.227  |
| 6096.245 | 286.705 | 4902.008 | 68.342  |         | 1320.782 | 376.248  |
| 5135.965 | 213.588 | 4927.067 | 92.037  |         | 1124.928 | 170.721  |
| 6522.056 | 307.544 | 4968.962 | 78.109  |         | 0.000    | 657.380  |
| 7319.491 | 759.058 | 4950.097 | 57.623  | #VALUE! |          | #VALUE!  |
| 6666.259 | 319.680 | 4942.932 | 97.398  |         | 0.000    | 871.509  |
| 6209.973 | 206.083 | 4950.445 | 56.400  | #NUM!   |          | #VALUE!  |
| 7114.480 | 399.907 | 4947.480 | 47.373  |         | 0.000    | 1046.334 |
| 5364.476 | 208.010 | 4939.422 | 67.079  |         | 1702.488 | 170.393  |
| 6137.996 | 233.273 | 4942.932 | 91.310  |         | 0.000    | 495.774  |
| 4702.074 | 236.029 | 4883.818 | 112.848 |         | 747.834  | 135.259  |
| 4859.444 | 274.060 | 4896.577 | 80.987  |         | 903.376  | 125.732  |
| 5414.752 | 289.137 | 4930.609 | 61.250  |         | 2366.063 | 213.322  |
| 5471.972 | 401.613 | 4946.432 | 85.074  |         | 2031.171 | 241.937  |
| 4795.607 | 193.545 | 4916.385 | 67.855  |         | 631.295  | 103.269  |
| 6464.406 | 478.433 | 4991.118 | 83.185  | #VALUE! |          | #VALUE!  |
| 5831.348 | 243.754 | 4972.394 | 77.975  | #VALUE! |          | #VALUE!  |
| 5511.083 | 153.221 | 4941.178 | 73.112  |         | 2805.842 | 237.815  |
| 3250.775 | 113.094 | 4654.711 | 70.101  |         | 395.354  | 26.699   |
| 4717.787 | 370.291 | 4896.577 | 62.297  |         | 693.415  | 100.448  |
| 5178.318 | 381.226 | 4891.124 | 62.466  |         | 1918.645 | 183.106  |
| 5377.789 | 211.212 | 4919.955 | 73.892  |         | 2457.337 | 201.044  |
| 4988.973 | 258.496 | 4903.814 | 62.074  |         | 1076.689 | 118.529  |
| 5346.274 | 166.637 | 4941.178 | 79.205  |         | 1575.284 | 176.862  |
| 4035.192 | 108.224 | 4825.806 | 64.516  |         | 456.029  | 47.839   |
| 6595.183 | 169.619 | 4982.640 | 77.574  |         | 382.865  | 701.468  |
| 5292.948 | 147.832 | 4953.404 | 108.999 |         | 1019.942 | 222.521  |
| 6637.246 | 288.995 | 4975.818 | 65.865  |         | 3177.747 | 1285.040 |
| 5181.409 | 313.737 | 4903.814 | 62.074  |         | 1639.353 | 155.770  |
| 5127.538 | 430.052 | 4918.171 | 117.099 |         | 1196.352 | 212.540  |
| 5492.170 | 185.213 | 4941.178 | 146.225 |         | 2811.695 | 409.860  |
| 5721.470 | 389.634 | 4948.178 | 72.857  |         | 408.994  | 283.488  |
| 5259.782 | 270.877 | 4941.178 | 188.874 |         | 1060.752 | 333.538  |
| 6369.373 | 626.101 | 4944.683 | 103.394 | #NUM!   |          | #VALUE!  |
| 6075.987 | 230.151 | 4951.665 | 78.790  |         | 3303.166 | 944.639  |
| 5171.485 | 188.461 | 4919.955 | 129.310 |         | 1336.083 | 223.248  |

|          |         |          |         |          |         |
|----------|---------|----------|---------|----------|---------|
| 6063.118 | 217.094 | 4956.877 | 78.585  | 1149.739 | 383.777 |
| 5634.438 | 242.105 | 4956.877 | 84.630  | 3177.038 | 395.950 |
| 5837.836 | 242.466 | 4955.142 | 133.105 | 865.667  | 477.770 |
| 5344.172 | 233.686 | 4951.665 | 157.581 | 1309.415 | 321.703 |
| 4436.663 | 244.585 | 4894.762 | 112.237 | 439.738  | 106.820 |

| Sample     | <sup>207</sup> Pb/ <sup>235</sup> U | Error 2σ | <sup>206</sup> Pb/ <sup>238</sup> U | Error 2σ | correlation_6_38 | <sup>238</sup> U/ <sup>206</sup> Pb |
|------------|-------------------------------------|----------|-------------------------------------|----------|------------------|-------------------------------------|
| BLR_1      | 2.263                               | 0.056    | 0.178                               | 0.003    | 0.351            | 5.618                               |
| BLR_2      | 2.130                               | 0.055    | 0.176                               | 0.003    | 0.319            | 5.688                               |
| BLR_3      | 2.108                               | 0.056    | 0.178                               | 0.003    | 0.156            | 5.624                               |
| BLR_4      | 2.091                               | 0.077    | 0.176                               | 0.003    | 0.366            | 5.698                               |
| BLR_5      | 2.242                               | 0.059    | 0.178                               | 0.004    | 0.559            | 5.609                               |
| BLR_6      | 2.124                               | 0.061    | 0.175                               | 0.003    | 0.516            | 5.727                               |
| BLR_7      | 2.210                               | 0.058    | 0.178                               | 0.003    | 0.199            | 5.615                               |
| BLR_8      | 2.181                               | 0.067    | 0.182                               | 0.003    | 0.298            | 5.501                               |
| BLR_9      | 2.209                               | 0.045    | 0.178                               | 0.002    | 0.245            | 5.624                               |
| BLR_10     | 2.223                               | 0.050    | 0.179                               | 0.002    | 0.218            | 5.583                               |
| BLR_11     | 2.062                               | 0.051    | 0.174                               | 0.003    | 0.128            | 5.741                               |
| BLR_12     | 2.158                               | 0.057    | 0.178                               | 0.003    | 0.182            | 5.618                               |
| BLR_13     | 2.256                               | 0.061    | 0.182                               | 0.003    | 0.362            | 5.488                               |
| BLR_14     | 2.217                               | 0.064    | 0.176                               | 0.003    | 0.422            | 5.672                               |
| BLR_15     | 2.103                               | 0.058    | 0.172                               | 0.002    | 0.418            | 5.804                               |
| BLR_16     | 2.182                               | 0.063    | 0.175                               | 0.003    | 0.344            | 5.718                               |
| BLR_17     | 2.228                               | 0.053    | 0.176                               | 0.003    | 0.115            | 5.688                               |
| BLR_18     | 2.290                               | 0.077    | 0.181                               | 0.002    | 0.203            | 5.522                               |
| BLR_19     | 2.165                               | 0.088    | 0.180                               | 0.003    | -0.008           | 5.546                               |
| BLR_20     | 2.203                               | 0.057    | 0.183                               | 0.003    | 0.344            | 5.476                               |
| T_MKED1_1  | 3.442                               | 0.083    | 0.266                               | 0.006    | 0.094            | 3.759                               |
| T_MKED1_2  | 3.520                               | 0.110    | 0.264                               | 0.005    | 0.641            | 3.788                               |
| T_MKED1_3  | 3.360                               | 0.120    | 0.269                               | 0.006    | 0.359            | 3.713                               |
| T_MKED1_4  | 3.520                               | 0.120    | 0.273                               | 0.005    | 0.572            | 3.660                               |
| T_MKED1_5  | 3.610                               | 0.140    | 0.270                               | 0.006    | 0.408            | 3.698                               |
| T_MKED1_6  | 3.500                               | 0.120    | 0.266                               | 0.007    | 0.662            | 3.759                               |
| T_MKED1_7  | 3.620                               | 0.160    | 0.269                               | 0.006    | 0.602            | 3.723                               |
| T_MKED1_8  | 3.499                               | 0.093    | 0.272                               | 0.005    | 0.253            | 3.671                               |
| T_MKED1_9  | 3.610                               | 0.140    | 0.274                               | 0.005    | 0.488            | 3.647                               |
| T_MKED1_10 | 3.569                               | 0.097    | 0.273                               | 0.006    | 0.561            | 3.667                               |
| T_MKED1_11 | 3.550                               | 0.120    | 0.273                               | 0.004    | 0.318            | 3.660                               |
| T_MKED1_12 | 3.596                               | 0.093    | 0.273                               | 0.004    | 0.089            | 3.668                               |
| T_MKED1_13 | 3.600                               | 0.110    | 0.273                               | 0.004    | 0.077            | 3.670                               |
| T_MKED1_14 | 3.550                               | 0.110    | 0.270                               | 0.006    | 0.343            | 3.705                               |
| T_MKED1_15 | 3.630                               | 0.120    | 0.271                               | 0.008    | 0.505            | 3.686                               |
| T_MKED1_16 | 3.480                               | 0.140    | 0.272                               | 0.005    | 0.311            | 3.676                               |
| T_MKED1_17 | 3.610                               | 0.130    | 0.274                               | 0.007    | 0.556            | 3.644                               |
| T_MKED1_18 | 3.514                               | 0.084    | 0.270                               | 0.004    | 0.277            | 3.702                               |
| T_MKED1_19 | 3.350                               | 0.150    | 0.263                               | 0.004    | 0.298            | 3.804                               |
| T_MKED1_20 | 3.470                               | 0.130    | 0.266                               | 0.005    | 0.476            | 3.766                               |
| ZA16_77_1  | 31.500                              | 5.400    | 0.295                               | 0.046    | 0.818            | 3.390                               |
| ZA16_77_2  | 16.000                              | 2.600    | 0.181                               | 0.018    | 0.752            | 5.525                               |
| ZA16_77_3  | 48.100                              | 8.300    | 0.477                               | 0.078    | 0.737            | 2.096                               |
| ZA16_77_4  | 105.000                             | 18.000   | 0.880                               | 0.150    | 0.527            | 1.136                               |
| ZA16_77_5  | 187.000                             | 29.000   | 1.680                               | 0.240    | 0.934            | 0.595                               |
| ZA16_77_6  | 164.000                             | 45.000   | 1.480                               | 0.430    | 0.893            | 0.676                               |
| ZA16_77_7  | 135.000                             | 27.000   | 1.330                               | 0.280    | 0.923            | 0.752                               |

|            |         |        |       |       |       |        |
|------------|---------|--------|-------|-------|-------|--------|
| ZA16_77_8  | 87.000  | 18.000 | 0.675 | 0.095 | 0.818 | 1.481  |
| ZA16_77_9  | 35.200  | 5.000  | 0.318 | 0.037 | 0.728 | 3.145  |
| ZA16_77_10 | 30.300  | 3.100  | 0.316 | 0.036 | 0.799 | 3.165  |
| ZA16_77_11 | 27.100  | 4.400  | 0.264 | 0.038 | 0.591 | 3.788  |
| ZA16_77_12 | 26.300  | 2.400  | 0.289 | 0.027 | 0.572 | 3.460  |
| ZA16_77_13 | 51.300  | 9.100  | 0.496 | 0.065 | 0.685 | 2.016  |
| ZA16_77_14 | 32.000  | 4.000  | 0.326 | 0.034 | 0.845 | 3.067  |
| ZA16_77_15 | 32.300  | 4.800  | 0.346 | 0.039 | 0.390 | 2.890  |
| ZA16_77_16 | 21.300  | 3.700  | 0.210 | 0.032 | 0.832 | 4.762  |
| ZA16_77_17 | 86.000  | 74.000 | 1.700 | 1.500 | 0.964 | 0.588  |
| ZA16_77_18 | 11.800  | 1.500  | 0.156 | 0.017 | 0.834 | 6.410  |
| ZA16_77_19 | 10.300  | 6.000  | 0.164 | 0.074 | 0.974 | 6.098  |
| ZA16_77_20 | 21.500  | 2.200  | 0.238 | 0.019 | 0.765 | 4.202  |
| ZA16_77_21 | 17.000  | 2.000  | 0.191 | 0.017 | 0.877 | 5.236  |
| ZA16_77_22 | 14.500  | 2.000  | 0.195 | 0.016 | 0.459 | 5.128  |
| ZA16_77_23 | 13.300  | 1.000  | 0.167 | 0.017 | 0.094 | 5.988  |
| ZA16_77_24 | 43.000  | 13.000 | 0.460 | 0.130 | 0.937 | 2.174  |
| ZA16_77_25 | 7.520   | 0.970  | 0.131 | 0.012 | 0.610 | 7.634  |
| ZA16_77_26 | 6.680   | 0.860  | 0.101 | 0.009 | 0.693 | 9.891  |
| ZA16_77_27 | 40.900  | 5.300  | 0.403 | 0.049 | 0.670 | 2.481  |
| ZA16_77_28 | 15.000  | 2.000  | 0.171 | 0.015 | 0.293 | 5.848  |
| ZA16_77_29 | 30.000  | 12.000 | 0.291 | 0.098 | 0.974 | 3.436  |
| ZA16_77_30 | 15.100  | 1.600  | 0.191 | 0.018 | 0.435 | 5.236  |
| ZA16_77_31 | 67.000  | 4.100  | 0.626 | 0.037 | 0.187 | 1.597  |
| ZA16_77_32 | 86.000  | 15.000 | 0.870 | 0.130 | 0.768 | 1.149  |
| ZA16_77_33 | 49.300  | 6.600  | 0.471 | 0.067 | 0.676 | 2.123  |
| ZA16_77_34 | 1.750   | 0.750  | 0.065 | 0.011 | 0.987 | 15.385 |
| ZA16_77_35 | 39.300  | 5.100  | 0.412 | 0.054 | 0.587 | 2.427  |
| ZA16_77_36 | 116.000 | 31.000 | 1.220 | 0.330 | 0.860 | 0.820  |
| ZA16_77_37 | 19.700  | 2.500  | 0.221 | 0.026 | 0.766 | 4.525  |
| ZA16_77_38 | 83.000  | 25.000 | 0.690 | 0.200 | 0.802 | 1.449  |
| ZA16_77_39 | 104.000 | 21.000 | 0.950 | 0.170 | 0.498 | 1.053  |
| ZA16_77_40 | 80.000  | 12.000 | 0.770 | 0.120 | 0.733 | 1.299  |
| ZA16_77_41 | 65.000  | 15.000 | 0.520 | 0.120 | 0.867 | 1.923  |
| ZA16_77_42 | 61.000  | 14.000 | 0.580 | 0.140 | 0.797 | 1.724  |
| ZA16_77_43 | 17.300  | 2.800  | 0.180 | 0.019 | 0.900 | 5.556  |
| ZA16_77_44 | 30.700  | 9.600  | 0.287 | 0.068 | 0.953 | 3.484  |
| ZA16_77_45 | 38.800  | 4.500  | 0.353 | 0.027 | 0.455 | 2.833  |
| ZA16_77_46 | 55.200  | 4.000  | 0.491 | 0.043 | 0.482 | 2.037  |
| ZA16_78_1  | 59.200  | 3.300  | 0.549 | 0.030 | 0.715 | 1.821  |
| ZA16_78_2  | 249.000 | 42.000 | 2.230 | 0.370 | 0.965 | 0.448  |
| ZA16_78_3  | 283.000 | 45.000 | 2.470 | 0.390 | 0.981 | 0.405  |
| ZA16_78_4  | 106.000 | 26.000 | 0.900 | 0.220 | 0.987 | 1.111  |
| ZA16_78_5  | 104.600 | 9.300  | 0.927 | 0.081 | 0.905 | 1.079  |
| ZA16_78_6  | 48.600  | 9.700  | 0.445 | 0.075 | 0.935 | 2.247  |
| ZA16_78_7  | 175.000 | 40.000 | 1.510 | 0.220 | 0.856 | 0.662  |
| ZA16_78_8  | 3.750   | 0.420  | 0.037 | 0.004 | 0.012 | 27.322 |
| ZA16_78_9  | 68.000  | 12.000 | 0.710 | 0.130 | 0.964 | 1.408  |
| ZA16_78_10 | 25.100  | 2.700  | 0.256 | 0.024 | 0.737 | 3.906  |

|             |         |         |       |       |       |        |
|-------------|---------|---------|-------|-------|-------|--------|
| ZA16_78_11  | 29.000  | 14.000  | 0.270 | 0.120 | 0.982 | 3.704  |
| ZA16_78_12  | 22.300  | 3.400   | 0.212 | 0.018 | 0.890 | 4.717  |
| ZA16_78_13  | 67.000  | 15.000  | 0.620 | 0.130 | 0.952 | 1.613  |
| ZA16_78_14  | 45.600  | 3.800   | 0.434 | 0.036 | 0.531 | 2.304  |
| ZA16_78_15  | 55.000  | 17.000  | 0.530 | 0.150 | 0.967 | 1.887  |
| ZA16_78_16  | 153.000 | 28.000  | 1.300 | 0.170 | 0.780 | 0.769  |
| ZA16_78_17  | 536.000 | 50.000  | 4.660 | 0.460 | 0.918 | 0.215  |
| ZA16_78_18  | 14.730  | 0.960   | 0.180 | 0.011 | 0.819 | 5.556  |
| ZA16_78_19  | 20.100  | 2.400   | 0.222 | 0.028 | 0.919 | 4.505  |
| ZA16_78_20  | 33.400  | 1.700   | 0.343 | 0.018 | 0.814 | 2.915  |
| ZA16_78_21  | 610.000 | 110.000 | 5.600 | 1.000 | 0.976 | 0.179  |
| ZA16_78_22  | 4.900   | 1.200   | 0.086 | 0.012 | 0.966 | 11.628 |
| ZA16_78_23  | 18.700  | 1.700   | 0.201 | 0.015 | 0.932 | 4.975  |
| ZA16_78_24  | 349.000 | 53.000  | 2.980 | 0.440 | 0.984 | 0.336  |
| ZA16_78_25  | 42.000  | 15.000  | 0.400 | 0.110 | 0.898 | 2.500  |
| ZA16_78_26  | 21.100  | 3.100   | 0.229 | 0.030 | 0.843 | 4.367  |
| ZA16_78_27  | 81.000  | 8.600   | 0.718 | 0.069 | 0.936 | 1.393  |
| ZA16_78_28  | 24.000  | 4.300   | 0.248 | 0.035 | 0.779 | 4.032  |
| ZA16_78_29  | 28.900  | 1.800   | 0.285 | 0.014 | 0.607 | 3.509  |
| ZA16_78_30  | 92.000  | 10.000  | 0.794 | 0.097 | 0.821 | 1.259  |
| ZA16_78_31  | 14.000  | 1.400   | 0.179 | 0.016 | 0.472 | 5.587  |
| ZA16_78_32  | 44.500  | 8.300   | 0.415 | 0.075 | 0.825 | 2.410  |
| ZA16_78_33  | 23.800  | 2.200   | 0.254 | 0.018 | 0.625 | 3.937  |
| ZA16_78_34  | 43.700  | 6.300   | 0.410 | 0.058 | 0.681 | 2.439  |
| ZA16_78_35  | 66.000  | 7.900   | 0.655 | 0.089 | 0.971 | 1.527  |
| ZA16_117_1  | 101.000 | 18.000  | 0.920 | 0.150 | 0.991 | 1.087  |
| ZA16_117_2  | 142.000 | 21.000  | 1.280 | 0.190 | 0.985 | 0.781  |
| ZA16_117_3  | 135.000 | 37.000  | 1.170 | 0.320 | 0.993 | 0.855  |
| ZA16_117_4  | 51.900  | 2.500   | 0.502 | 0.028 | 0.837 | 1.992  |
| ZA16_117_5  | 162.000 | 57.000  | 1.470 | 0.510 | 0.996 | 0.680  |
| ZA16_117_6  | 191.200 | 9.000   | 1.750 | 0.084 | 0.914 | 0.571  |
| ZA16_117_7  | 182.000 | 33.000  | 1.630 | 0.260 | 0.982 | 0.613  |
| ZA16_117_8  | 880.000 | 240.000 | 8.500 | 2.400 | 0.995 | 0.118  |
| ZA16_117_9  | 38.200  | 3.900   | 0.373 | 0.034 | 0.928 | 2.681  |
| ZA16_117_10 | 33.600  | 5.200   | 0.328 | 0.038 | 0.933 | 3.049  |
| ZA16_117_11 | 275.000 | 27.000  | 2.410 | 0.220 | 0.979 | 0.415  |
| ZA16_117_12 | 100.000 | 14.000  | 0.890 | 0.110 | 0.985 | 1.124  |
| ZA16_117_13 | 156.000 | 87.000  | 1.390 | 0.740 | 0.998 | 0.719  |
| ZA16_117_14 | 205.000 | 11.000  | 1.820 | 0.100 | 0.941 | 0.549  |
| ZA16_117_15 | 37.000  | 8.900   | 0.386 | 0.087 | 0.976 | 2.591  |
| ZA16_117_16 | 56.400  | 6.400   | 0.544 | 0.062 | 0.896 | 1.838  |
| ZA16_117_17 | 170.000 | 46.000  | 1.570 | 0.410 | 0.995 | 0.637  |
| ZA16_117_18 | 24.600  | 2.400   | 0.259 | 0.022 | 0.897 | 3.861  |
| ZA16_117_19 | 57.300  | 7.700   | 0.562 | 0.074 | 0.953 | 1.779  |
| ZA16_117_20 | 39.800  | 3.900   | 0.372 | 0.029 | 0.934 | 2.688  |
| ZA16_117_21 | 57.800  | 9.200   | 0.547 | 0.072 | 0.982 | 1.828  |
| ZA16_117_22 | 104.000 | 11.000  | 0.960 | 0.089 | 0.985 | 1.042  |
| ZA16_117_23 | 88.000  | 9.800   | 0.778 | 0.080 | 0.960 | 1.285  |
| ZA16_117_24 | 218.000 | 26.000  | 1.950 | 0.240 | 0.985 | 0.513  |



|             |         |        |       |       |       |       |
|-------------|---------|--------|-------|-------|-------|-------|
| ZA16_117_25 | 59.800  | 4.600  | 0.560 | 0.041 | 0.895 | 1.786 |
| ZA16_117_26 | 151.000 | 15.000 | 1.350 | 0.130 | 0.974 | 0.741 |
| ZA16_117_27 | 227.000 | 20.000 | 2.040 | 0.170 | 0.967 | 0.490 |
| ZA16_117_28 | 156.700 | 8.000  | 1.400 | 0.078 | 0.858 | 0.714 |
| ZA16_117_29 | 93.300  | 5.000  | 0.856 | 0.042 | 0.826 | 1.168 |
| ZA184_1     | 157.000 | 16.000 | 1.440 | 0.130 | 0.760 | 0.694 |
| ZA184_2     | 124.000 | 11.000 | 1.052 | 0.091 | 0.822 | 0.951 |
| ZA184_3     | 494.000 | 73.000 | 4.390 | 0.640 | 0.939 | 0.228 |
| ZA184_4     | 105.000 | 31.000 | 0.860 | 0.250 | 0.895 | 1.163 |
| ZA184_5     | 255.000 | 27.000 | 1.960 | 0.240 | 0.588 | 0.510 |
| ZA184_6     | 27.100  | 6.700  | 0.279 | 0.056 | 0.930 | 3.584 |
| ZA184_7     | 161.000 | 14.000 | 1.390 | 0.120 | 0.814 | 0.719 |
| ZA184_8     | 27.900  | 2.600  | 0.288 | 0.030 | 0.681 | 3.472 |
| ZA184_9     | 29.400  | 2.700  | 0.311 | 0.030 | 0.746 | 3.215 |
| ZA184_10    | 99.000  | 21.000 | 0.890 | 0.200 | 0.901 | 1.124 |
| ZA184_11    | 173.000 | 35.000 | 1.460 | 0.280 | 0.937 | 0.685 |
| ZA184_12    | 119.000 | 10.000 | 1.095 | 0.066 | 0.485 | 0.913 |
| ZA184_13    | 505.000 | 29.000 | 4.400 | 0.270 | 0.862 | 0.227 |
| ZA184_14    | 51.800  | 5.200  | 0.434 | 0.038 | 0.687 | 2.304 |
| ZA184_15    | 82.000  | 14.000 | 0.730 | 0.120 | 0.855 | 1.370 |
| ZA184_16    | 65.200  | 6.800  | 0.669 | 0.078 | 0.567 | 1.495 |
| ZA184_17    | 41.900  | 4.900  | 0.397 | 0.035 | 0.540 | 2.519 |
| ZA184_18    | 91.600  | 9.800  | 0.815 | 0.074 | 0.593 | 1.227 |
| ZA184_19    | 55.900  | 4.200  | 0.498 | 0.032 | 0.610 | 2.008 |
| ZA184_20    | 7.800   | 1.600  | 0.112 | 0.013 | 0.746 | 8.929 |
| ZA184_21    | 13.100  | 1.500  | 0.162 | 0.015 | 0.950 | 6.173 |
| ZA184_22    | 48.600  | 7.100  | 0.451 | 0.056 | 0.768 | 2.217 |
| ZA184_23    | 14.700  | 2.300  | 0.176 | 0.021 | 0.825 | 5.682 |
| ZA184_24    | 153.000 | 16.000 | 1.360 | 0.200 | 0.860 | 0.735 |
| ZA184_25    | 87.000  | 13.000 | 0.820 | 0.120 | 0.942 | 1.220 |



| Error 2σ | <sup>207</sup> Pb/ <sup>206</sup> Pb | Error 2σ | Correlation_38_ | Age <sup>206</sup> Pb/ <sup>238</sup> U | Error 2σ | FinalAge <sup>207</sup> Pb |
|----------|--------------------------------------|----------|-----------------|-----------------------------------------|----------|----------------------------|
| 0.092    | 0.092                                | 0.003    | 0.240           | 1056.039                                | 17.205   | 1200.840                   |
| 0.097    | 0.089                                | 0.002    | 0.407           | 1043.989                                | 17.816   | 1158.586                   |
| 0.095    | 0.086                                | 0.002    | 0.409           | 1054.945                                | 17.800   | 1151.423                   |
| 0.097    | 0.086                                | 0.003    | 0.110           | 1042.344                                | 17.818   | 1145.854                   |
| 0.120    | 0.090                                | 0.002    | 0.243           | 1057.681                                | 22.542   | 1194.284                   |
| 0.085    | 0.088                                | 0.002    | 0.039           | 1037.406                                | 15.448   | 1156.637                   |
| 0.079    | 0.089                                | 0.002    | 0.339           | 1056.586                                | 14.831   | 1184.212                   |
| 0.088    | 0.087                                | 0.003    | 0.215           | 1076.801                                | 17.177   | 1174.997                   |
| 0.076    | 0.091                                | 0.002    | 0.359           | 1054.945                                | 14.240   | 1183.895                   |
| 0.065    | 0.090                                | 0.002    | 0.372           | 1062.056                                | 12.453   | 1188.316                   |
| 0.092    | 0.086                                | 0.002    | 0.401           | 1035.211                                | 16.639   | 1136.283                   |
| 0.088    | 0.088                                | 0.002    | 0.376           | 1056.039                                | 16.612   | 1167.628                   |
| 0.090    | 0.090                                | 0.003    | 0.114           | 1078.982                                | 17.766   | 1198.659                   |
| 0.084    | 0.091                                | 0.002    | 0.314           | 1046.730                                | 15.437   | 1186.424                   |
| 0.081    | 0.088                                | 0.002    | 0.150           | 1024.771                                | 14.274   | 1149.789                   |
| 0.101    | 0.089                                | 0.003    | 0.221           | 1039.053                                | 18.417   | 1175.316                   |
| 0.084    | 0.092                                | 0.003    | 0.435           | 1043.989                                | 15.440   | 1189.890                   |
| 0.073    | 0.092                                | 0.003    | 0.198           | 1072.981                                | 14.220   | 1209.207                   |
| 0.086    | 0.088                                | 0.004    | 0.352           | 1068.613                                | 16.595   | 1169.877                   |
| 0.075    | 0.088                                | 0.002    | 0.129           | 1081.163                                | 14.802   | 1181.995                   |
|          |                                      |          |                 |                                         |          |                            |
| 0.078    | 0.093                                | 0.003    | 0.554           | 1520.466                                | 31.438   | 1514.042                   |
| 0.070    | 0.097                                | 0.003    | -0.266          | 1510.274                                | 28.032   | 1531.718                   |
| 0.076    | 0.092                                | 0.003    | 0.217           | 1537.248                                | 31.396   | 1495.123                   |
| 0.064    | 0.094                                | 0.003    | -0.005          | 1557.024                                | 27.356   | 1531.718                   |
| 0.078    | 0.096                                | 0.003    | 0.283           | 1542.832                                | 32.523   | 1551.737                   |
| 0.095    | 0.096                                | 0.002    | 0.037           | 1520.466                                | 38.297   | 1527.215                   |
| 0.078    | 0.097                                | 0.004    | 0.052           | 1533.692                                | 31.976   | 1553.937                   |
| 0.067    | 0.093                                | 0.002    | 0.498           | 1552.973                                | 28.505   | 1526.989                   |
| 0.068    | 0.095                                | 0.003    | 0.115           | 1562.086                                | 29.054   | 1551.737                   |
| 0.074    | 0.094                                | 0.002    | 0.219           | 1554.492                                | 31.352   | 1542.666                   |
| 0.054    | 0.094                                | 0.003    | 0.151           | 1557.024                                | 22.797   | 1538.435                   |
| 0.052    | 0.096                                | 0.003    | 0.345           | 1553.986                                | 22.232   | 1548.648                   |
| 0.057    | 0.097                                | 0.003    | 0.353           | 1553.479                                | 23.944   | 1549.532                   |
| 0.085    | 0.096                                | 0.003    | 0.344           | 1540.294                                | 35.383   | 1538.435                   |
| 0.109    | 0.098                                | 0.003    | 0.322           | 1547.397                                | 45.629   | 1556.132                   |
| 0.065    | 0.094                                | 0.003    | 0.100           | 1550.946                                | 27.370   | 1522.692                   |
| 0.086    | 0.097                                | 0.003    | 0.089           | 1563.097                                | 37.027   | 1551.737                   |
| 0.055    | 0.093                                | 0.002    | 0.330           | 1541.310                                | 22.826   | 1530.369                   |
| 0.064    | 0.095                                | 0.003    | 0.202           | 1504.662                                | 25.183   | 1492.792                   |
| 0.077    | 0.095                                | 0.003    | 0.064           | 1517.920                                | 30.873   | 1520.423                   |
|          |                                      |          |                 |                                         |          |                            |
| 0.529    | 0.690                                | 0.085    | 0.398           | 1666.467                                | 259.856  | 3534.792                   |
| 0.549    | 0.680                                | 0.110    | 0.193           | 1072.435                                | 106.651  | 2876.797                   |
| 0.343    | 0.740                                | 0.120    | 0.521           | 2514.185                                | 411.125  | 3953.758                   |
| 0.194    | 0.810                                | 0.160    | 0.593           | 4069.439                                | 693.654  | 4735.177                   |
| 0.085    | 0.825                                | 0.043    | -0.039          | 6354.983                                | 907.855  | 5316.994                   |
| 0.196    | 0.816                                | 0.093    | 0.321           | 5855.011                                | 1701.118 | 5184.491                   |
| 0.158    | 0.776                                | 0.054    | -0.113          | 5452.817                                | 1147.962 | 4988.227                   |

|       |       |       |        |          |          |          |
|-------|-------|-------|--------|----------|----------|----------|
| 0.209 | 0.828 | 0.087 | -0.272 | 3325.145 | 467.983  | 4546.212 |
| 0.366 | 0.783 | 0.079 | 0.289  | 1779.954 | 207.102  | 3644.270 |
| 0.361 | 0.712 | 0.051 | 0.370  | 1770.165 | 201.664  | 3496.591 |
| 0.545 | 0.750 | 0.084 | 0.162  | 1510.274 | 217.388  | 3387.084 |
| 0.323 | 0.668 | 0.062 | 0.356  | 1636.530 | 152.894  | 3357.757 |
| 0.264 | 0.750 | 0.100 | 0.070  | 2596.583 | 340.278  | 4017.867 |
| 0.320 | 0.708 | 0.049 | 0.179  | 1818.965 | 189.708  | 3550.295 |
| 0.326 | 0.690 | 0.110 | 0.332  | 1915.470 | 215.906  | 3559.484 |
| 0.726 | 0.699 | 0.073 | 0.185  | 1228.818 | 187.248  | 3152.345 |
| 0.519 | 0.715 | 0.064 | 0.199  | 6402.912 | 5649.629 | 4534.607 |
| 0.699 | 0.545 | 0.049 | 0.252  | 934.509  | 101.838  | 2588.663 |
| 2.751 | 0.444 | 0.080 | -0.805 | 978.968  | 441.729  | 2462.104 |
| 0.335 | 0.657 | 0.038 | 0.208  | 1376.291 | 109.872  | 3161.411 |
| 0.466 | 0.619 | 0.033 | 0.104  | 1126.790 | 100.290  | 2934.835 |
| 0.421 | 0.518 | 0.064 | 0.234  | 1148.404 | 94.228   | 2783.003 |
| 0.610 | 0.571 | 0.063 | 0.726  | 995.561  | 101.345  | 2701.182 |
| 0.614 | 0.722 | 0.069 | -0.370 | 2439.558 | 689.440  | 3842.402 |
| 0.699 | 0.465 | 0.060 | -0.074 | 793.568  | 72.693   | 2175.373 |
| 0.910 | 0.478 | 0.058 | 0.348  | 620.852  | 57.111   | 2069.980 |
| 0.302 | 0.763 | 0.074 | 0.136  | 2182.838 | 265.407  | 3792.746 |
| 0.513 | 0.643 | 0.082 | 0.365  | 1017.619 | 89.265   | 2815.240 |
| 1.157 | 0.625 | 0.049 | -0.579 | 1646.524 | 554.500  | 3486.812 |
| 0.493 | 0.612 | 0.071 | 0.355  | 1126.790 | 106.190  | 2821.566 |
| 0.094 | 0.767 | 0.052 | 0.651  | 3133.750 | 185.222  | 4284.417 |
| 0.172 | 0.760 | 0.100 | -0.023 | 4035.058 | 602.940  | 4534.607 |
| 0.302 | 0.781 | 0.092 | 0.661  | 2487.945 | 353.911  | 3978.276 |
| 2.604 | 0.165 | 0.031 | -0.891 | 405.962  | 68.701   | 1027.162 |
| 0.318 | 0.722 | 0.083 | 0.336  | 2224.059 | 291.503  | 3753.213 |
| 0.222 | 0.737 | 0.086 | 0.137  | 5141.062 | 1390.615 | 4835.431 |
| 0.532 | 0.689 | 0.057 | 0.184  | 1287.157 | 151.430  | 3076.746 |
| 0.420 | 0.789 | 0.097 | -0.099 | 3382.617 | 980.469  | 4498.976 |
| 0.188 | 0.800 | 0.120 | 0.046  | 4305.105 | 770.387  | 4725.552 |
| 0.202 | 0.758 | 0.086 | 0.558  | 3680.771 | 573.627  | 4462.049 |
| 0.444 | 0.801 | 0.094 | -0.017 | 2699.180 | 622.888  | 4254.104 |
| 0.416 | 0.770 | 0.100 | 0.410  | 2948.750 | 711.767  | 4190.622 |
| 0.586 | 0.663 | 0.044 | -0.355 | 1066.975 | 112.625  | 2951.618 |
| 0.826 | 0.614 | 0.084 | -0.446 | 1626.520 | 385.378  | 3509.485 |
| 0.217 | 0.798 | 0.082 | 0.340  | 1948.908 | 149.067  | 3740.536 |
| 0.178 | 0.818 | 0.061 | 0.575  | 2575.001 | 225.509  | 4090.894 |
| 0.100 | 0.759 | 0.035 | 0.304  | 2821.012 | 154.154  | 4160.707 |
| 0.074 | 0.828 | 0.032 | -0.140 | 7558.305 | 1254.069 | 5606.398 |
| 0.064 | 0.874 | 0.025 | -0.301 | 8020.336 | 1266.369 | 5735.873 |
| 0.272 | 0.800 | 0.027 | -0.372 | 4137.656 | 1011.427 | 4744.711 |
| 0.094 | 0.819 | 0.025 | 0.051  | 4228.618 | 369.491  | 4731.338 |
| 0.379 | 0.729 | 0.051 | 0.003  | 2372.985 | 399.941  | 3964.046 |
| 0.096 | 0.816 | 0.071 | -0.122 | 5932.524 | 864.341  | 5250.022 |
| 3.210 | 0.750 | 0.120 | 0.670  | 231.724  | 27.224   | 1582.114 |
| 0.258 | 0.713 | 0.058 | 0.343  | 3458.458 | 633.239  | 4299.240 |
| 0.366 | 0.703 | 0.055 | 0.005  | 1469.345 | 137.751  | 3312.114 |

|       |       |       |        |           |          |          |
|-------|-------|-------|--------|-----------|----------|----------|
| 1.646 | 0.704 | 0.083 | -0.493 | 1540.802  | 684.801  | 3453.518 |
| 0.400 | 0.718 | 0.054 | -0.112 | 1239.464  | 105.238  | 3196.886 |
| 0.338 | 0.732 | 0.042 | -0.270 | 3109.919  | 652.080  | 4284.417 |
| 0.191 | 0.771 | 0.063 | 0.519  | 2323.724  | 192.751  | 3900.696 |
| 0.534 | 0.657 | 0.048 | 0.281  | 2741.452  | 775.883  | 4087.274 |
| 0.101 | 0.771 | 0.057 | 0.185  | 5369.277  | 702.136  | 5114.436 |
| 0.021 | 0.830 | 0.035 | 0.238  | 11174.368 | 1103.049 | 6382.696 |
| 0.340 | 0.607 | 0.027 | 0.100  | 1066.975  | 65.204   | 2797.959 |
| 0.568 | 0.680 | 0.027 | -0.024 | 1292.434  | 163.010  | 3096.180 |
| 0.153 | 0.700 | 0.022 | 0.143  | 1901.086  | 99.765   | 3592.483 |
| 0.032 | 0.783 | 0.022 | -0.020 | 12164.833 | 2172.292 | 6513.781 |
| 1.622 | 0.382 | 0.049 | -0.732 | 531.837   | 74.210   | 1802.257 |
| 0.371 | 0.684 | 0.026 | -0.448 | 1180.690  | 88.111   | 3026.470 |
| 0.050 | 0.840 | 0.025 | 0.033  | 8904.315  | 1314.731 | 5948.046 |
| 0.688 | 0.740 | 0.120 | 0.079  | 2169.039  | 596.486  | 3819.059 |
| 0.572 | 0.669 | 0.046 | -0.102 | 1329.256  | 174.138  | 3143.197 |
| 0.134 | 0.825 | 0.043 | 0.198  | 3488.547  | 335.250  | 4474.508 |
| 0.569 | 0.670 | 0.081 | -0.117 | 1428.153  | 201.554  | 3268.392 |
| 0.172 | 0.720 | 0.041 | 0.520  | 1616.495  | 79.407   | 3450.128 |
| 0.154 | 0.881 | 0.079 | 0.577  | 3767.592  | 460.273  | 4602.325 |
| 0.499 | 0.623 | 0.066 | 0.341  | 1061.509  | 94.884   | 2749.708 |
| 0.435 | 0.800 | 0.120 | 0.422  | 2237.741  | 404.411  | 3876.440 |
| 0.279 | 0.691 | 0.058 | 0.246  | 1459.071  | 103.399  | 3260.236 |
| 0.345 | 0.759 | 0.085 | 0.415  | 2214.922  | 313.330  | 3858.429 |
| 0.207 | 0.766 | 0.040 | -0.267 | 3247.710  | 441.292  | 4269.374 |
| 0.177 | 0.789 | 0.019 | -0.328 | 4205.158  | 685.624  | 4696.119 |
| 0.116 | 0.808 | 0.017 | -0.133 | 5312.976  | 788.645  | 5039.188 |
| 0.234 | 0.826 | 0.034 | 0.104  | 4994.212  | 1365.938 | 4988.227 |
| 0.111 | 0.741 | 0.024 | 0.432  | 2622.386  | 146.269  | 4029.449 |
| 0.236 | 0.763 | 0.034 | -0.468 | 5828.965  | 2022.294 | 5172.108 |
| 0.027 | 0.797 | 0.016 | 0.226  | 6521.198  | 313.018  | 5339.429 |
| 0.098 | 0.804 | 0.036 | -0.600 | 6233.578  | 994.313  | 5289.624 |
| 0.033 | 0.824 | 0.015 | -0.048 | 14512.759 | 4097.720 | 6885.371 |
| 0.244 | 0.754 | 0.031 | -0.075 | 2043.501  | 186.271  | 3725.112 |
| 0.353 | 0.724 | 0.051 | -0.159 | 1828.680  | 211.859  | 3598.369 |
| 0.038 | 0.841 | 0.016 | 0.280  | 7907.896  | 721.883  | 5706.860 |
| 0.139 | 0.795 | 0.020 | -0.034 | 4103.638  | 507.191  | 4686.115 |
| 0.383 | 0.766 | 0.033 | -0.300 | 5616.718  | 2990.195 | 5134.026 |
| 0.030 | 0.827 | 0.018 | 0.222  | 6683.235  | 367.211  | 5409.835 |
| 0.584 | 0.722 | 0.030 | -0.357 | 2104.251  | 474.274  | 3693.543 |
| 0.210 | 0.774 | 0.029 | 0.192  | 2800.171  | 319.137  | 4112.346 |
| 0.166 | 0.787 | 0.023 | -0.468 | 6084.808  | 1589.026 | 5220.758 |
| 0.328 | 0.698 | 0.029 | -0.337 | 1484.724  | 126.116  | 3292.473 |
| 0.234 | 0.763 | 0.021 | -0.214 | 2874.888  | 378.544  | 4128.143 |
| 0.210 | 0.759 | 0.027 | -0.132 | 2038.804  | 158.939  | 3765.733 |
| 0.241 | 0.747 | 0.032 | -0.726 | 2812.684  | 370.225  | 4136.815 |
| 0.097 | 0.782 | 0.017 | -0.230 | 4338.079  | 402.176  | 4725.552 |
| 0.132 | 0.795 | 0.023 | -0.269 | 3709.841  | 381.475  | 4557.685 |
| 0.063 | 0.823 | 0.017 | 0.201  | 6973.764  | 858.309  | 5471.972 |

|       |       |       |        |           |          |          |
|-------|-------|-------|--------|-----------|----------|----------|
| 0.131 | 0.775 | 0.028 | 0.279  | 2866.629  | 209.878  | 4170.777 |
| 0.071 | 0.809 | 0.016 | -0.194 | 5507.915  | 530.392  | 5101.163 |
| 0.041 | 0.831 | 0.022 | -0.203 | 7167.494  | 597.291  | 5512.866 |
| 0.040 | 0.831 | 0.025 | 0.455  | 5643.634  | 314.431  | 5138.543 |
| 0.057 | 0.789 | 0.019 | 0.085  | 3986.615  | 195.605  | 4616.420 |
| 0.063 | 0.790 | 0.055 | 0.182  | 5750.189  | 519.114  | 5140.473 |
| 0.082 | 0.810 | 0.066 | 0.561  | 4633.779  | 400.831  | 4902.588 |
| 0.033 | 0.781 | 0.040 | 0.293  | 10859.277 | 1583.129 | 6300.003 |
| 0.338 | 0.820 | 0.110 | 0.362  | 4000.493  | 1162.934 | 4735.177 |
| 0.062 | 0.900 | 0.120 | 0.418  | 6995.579  | 856.602  | 5630.479 |
| 0.719 | 0.647 | 0.048 | -0.274 | 1586.324  | 318.402  | 3387.084 |
| 0.062 | 0.837 | 0.044 | 0.463  | 5616.718  | 484.897  | 5165.859 |
| 0.362 | 0.694 | 0.059 | 0.614  | 1631.527  | 169.951  | 3415.588 |
| 0.310 | 0.692 | 0.047 | 0.429  | 1745.626  | 168.388  | 3466.967 |
| 0.252 | 0.806 | 0.052 | 0.129  | 4103.638  | 922.166  | 4676.012 |
| 0.131 | 0.802 | 0.058 | 0.082  | 5802.813  | 1112.868 | 5238.417 |
| 0.055 | 0.781 | 0.048 | 0.301  | 4767.469  | 287.354  | 4861.138 |
| 0.014 | 0.838 | 0.026 | 0.160  | 10871.226 | 667.098  | 6322.320 |
| 0.202 | 0.823 | 0.064 | 0.295  | 2323.724  | 203.460  | 4027.528 |
| 0.225 | 0.791 | 0.073 | 0.223  | 3533.418  | 580.836  | 4486.816 |
| 0.174 | 0.718 | 0.077 | 0.478  | 3302.012  | 384.988  | 4257.177 |
| 0.222 | 0.740 | 0.081 | 0.490  | 2155.211  | 190.006  | 3816.695 |
| 0.111 | 0.832 | 0.078 | 0.243  | 3842.614  | 348.900  | 4597.948 |
| 0.129 | 0.793 | 0.063 | -0.031 | 2605.195  | 167.402  | 4103.463 |
| 1.036 | 0.475 | 0.066 | -0.275 | 684.353   | 79.434   | 2208.206 |
| 0.572 | 0.589 | 0.024 | -0.360 | 967.882   | 89.619   | 2686.881 |
| 0.275 | 0.807 | 0.084 | 0.339  | 2399.697  | 297.967  | 3964.046 |
| 0.678 | 0.614 | 0.052 | -0.194 | 1045.085  | 124.698  | 2796.020 |
| 0.108 | 0.828 | 0.067 | 0.681  | 5535.288  | 814.013  | 5114.436 |
| 0.178 | 0.757 | 0.041 | 0.010  | 3860.348  | 564.929  | 4546.212 |





| Error 2σ | FinalAge <sup>207</sup> Pb | Error 2σ | FinalAge 207Pb corr | Error 2σ |
|----------|----------------------------|----------|---------------------|----------|
| 29.716   | 1473.566                   | 39.912   | 1034.455            | 16.528   |
| 29.917   | 1399.849                   | 34.681   | 1026.331            | 17.090   |
| 30.588   | 1335.933                   | 34.215   | 1041.105            | 17.142   |
| 42.195   | 1340.429                   | 43.591   | 1027.880            | 17.268   |
| 31.429   | 1431.882                   | 31.714   | 1038.571            | 21.475   |
| 33.218   | 1382.484                   | 34.562   | 1020.531            | 14.884   |
| 31.079   | 1412.744                   | 36.346   | 1038.543            | 14.328   |
| 36.096   | 1360.495                   | 39.095   | 1062.308            | 16.624   |
| 24.117   | 1442.411                   | 31.771   | 1035.156            | 13.687   |
| 26.728   | 1433.994                   | 30.139   | 1042.940            | 12.014   |
| 28.104   | 1333.681                   | 37.306   | 1020.896            | 16.076   |
| 30.841   | 1382.484                   | 37.704   | 1039.682            | 16.032   |
| 32.411   | 1423.406                   | 42.750   | 1060.956            | 17.168   |
| 34.249   | 1448.694                   | 36.575   | 1026.375            | 14.853   |
| 31.711   | 1373.727                   | 31.364   | 1008.038            | 13.742   |
| 33.934   | 1408.458                   | 42.633   | 1020.787            | 17.739   |
| 28.305   | 1463.252                   | 39.849   | 1022.728            | 14.888   |
| 40.659   | 1461.181                   | 50.990   | 1052.557            | 14.014   |
| 47.552   | 1384.666                   | 64.440   | 1052.505            | 16.543   |
| 30.583   | 1378.112                   | 34.531   | 1065.817            | 14.329   |
| 36.509   | 1487.888                   | 43.197   | 1523.232            | 30.815   |
| 47.866   | 1573.001                   | 54.966   | 1504.857            | 27.610   |
| 53.397   | 1465.320                   | 47.834   | 1543.420            | 30.956   |
| 52.218   | 1512.128                   | 41.736   | 1561.021            | 26.962   |
| 60.178   | 1539.924                   | 53.156   | 1543.089            | 32.009   |
| 52.362   | 1539.924                   | 38.659   | 1518.786            | 37.227   |
| 68.682   | 1557.526                   | 62.947   | 1531.591            | 31.625   |
| 40.586   | 1483.809                   | 36.775   | 1559.046            | 28.014   |
| 60.178   | 1530.055                   | 45.049   | 1564.970            | 28.635   |
| 41.927   | 1510.122                   | 38.515   | 1558.429            | 30.738   |
| 52.003   | 1514.130                   | 48.170   | 1560.846            | 22.759   |
| 40.051   | 1547.772                   | 45.143   | 1554.544            | 22.094   |
| 47.347   | 1559.469                   | 48.431   | 1552.940            | 23.770   |
| 47.670   | 1555.580                   | 53.251   | 1538.939            | 34.695   |
| 51.442   | 1594.022                   | 48.598   | 1543.176            | 44.363   |
| 61.258   | 1498.035                   | 54.474   | 1555.604            | 27.247   |
| 55.880   | 1574.924                   | 53.360   | 1562.015            | 36.320   |
| 36.583   | 1481.766                   | 31.969   | 1546.469            | 22.445   |
| 66.841   | 1522.114                   | 54.648   | 1503.189            | 24.988   |
| 56.961   | 1534.010                   | 51.509   | 1516.537            | 30.326   |
| 605.964  | 4710.033                   | 580.221  | 392.959             | 200.363  |
| 467.479  | 4689.023                   | 758.518  | 245.631             | 157.484  |
| 682.249  | 4810.418                   | 780.068  | 465.316             | 436.577  |
| 811.745  | 4939.422                   | 975.688  | 330.614             | 1083.929 |
| 824.561  | 4965.520                   | 258.809  | 835.558             | 532.600  |
| 1422.574 | 4949.923                   | 564.146  | 848.010             | 1002.931 |
| 997.645  | 4878.312                   | 339.470  | 1570.974            | 566.641  |

|          |          |         |           |          |
|----------|----------|---------|-----------|----------|
| 940.596  | 4970.679 | 522.281 | 67.214    | 475.481  |
| 517.652  | 4891.124 | 493.485 | 160.279   | 200.902  |
| 357.737  | 4755.129 | 340.606 | 363.478   | 130.747  |
| 549.932  | 4829.625 | 540.918 | 208.059   | 177.380  |
| 306.411  | 4663.371 | 432.828 | 438.751   | 141.606  |
| 712.721  | 4829.625 | 643.950 | 440.561   | 378.961  |
| 443.787  | 4747.041 | 328.538 | 388.232   | 128.974  |
| 528.964  | 4710.033 | 750.875 | 470.812   | 290.457  |
| 547.590  | 4728.664 | 493.838 | 254.143   | 125.898  |
| 3901.872 | 4761.163 | 426.174 | 2816.309  | 3305.071 |
| 329.067  | 4367.791 | 392.701 | 382.578   | 71.414   |
| 1434.235 | 4065.230 | 732.474 | 533.375   | 254.291  |
| 323.493  | 4639.420 | 268.338 | 376.535   | 75.876   |
| 345.275  | 4553.243 | 242.742 | 357.428   | 58.120   |
| 383.862  | 4293.266 | 530.442 | 524.253   | 101.988  |
| 203.096  | 4435.883 | 489.423 | 375.609   | 88.821   |
| 1161.656 | 4775.137 | 456.350 | 522.825   | 277.438  |
| 280.600  | 4133.909 | 533.408 | 402.866   | 69.883   |
| 266.494  | 4174.756 | 506.560 | 299.260   | 52.925   |
| 491.481  | 4854.190 | 470.786 | 290.856   | 234.574  |
| 375.365  | 4608.308 | 587.685 | 284.107   | 111.695  |
| 1394.725 | 4567.221 | 358.070 | 547.612   | 208.941  |
| 298.974  | 4536.749 | 526.322 | 368.427   | 109.309  |
| 262.181  | 4861.659 | 329.604 | 487.491   | 247.424  |
| 790.920  | 4848.561 | 637.969 | 869.667   | 624.755  |
| 532.589  | 4887.476 | 575.733 | 268.635   | 339.939  |
| 440.212  | 2507.554 | 471.116 | 351.289   | 60.450   |
| 487.058  | 4775.137 | 548.942 | 457.427   | 264.417  |
| 1292.227 | 4804.602 | 560.646 | 1979.795  | 847.913  |
| 390.450  | 4707.946 | 389.482 | 287.583   | 103.734  |
| 1355.113 | 4902.008 | 602.655 | 390.045   | 522.286  |
| 954.198  | 4921.737 | 738.260 | 513.290   | 854.391  |
| 669.307  | 4844.795 | 549.673 | 736.457   | 489.066  |
| 981.716  | 4923.516 | 577.791 | 196.824   | 388.720  |
| 961.782  | 4867.233 | 632.108 | 420.946   | 450.886  |
| 477.719  | 4652.537 | 308.766 | 269.914   | 68.248   |
| 1097.429 | 4541.482 | 621.310 | 565.516   | 220.936  |
| 433.825  | 4918.171 | 505.376 | 130.615   | 231.936  |
| 296.442  | 4953.404 | 369.386 | 94.254    | 242.520  |
|          |          |         |           |          |
| 231.931  | 4846.679 | 223.496 | 452.590   | 149.723  |
| 945.657  | 4970.679 | 192.104 | 2113.084  | 599.165  |
| 912.065  | 5047.387 | 144.376 | -7773.769 | 3123.516 |
| 1163.797 | 4921.737 | 166.109 | 465.880   | 220.223  |
| 420.664  | 4955.142 | 151.256 | 245.230   | 191.232  |
| 791.178  | 4788.968 | 335.031 | 473.007   | 188.582  |
| 1200.005 | 4949.923 | 430.692 | 897.541   | 765.974  |
| 177.197  | 4829.625 | 772.740 | 25.991    | 35.883   |
| 758.689  | 4757.143 | 386.977 | 985.294   | 334.588  |
| 356.283  | 4736.863 | 370.594 | 306.856   | 113.107  |

|          |          |         |          |          |
|----------|----------|---------|----------|----------|
| 1667.216 | 4738.905 | 558.706 | 323.205  | 223.438  |
| 487.418  | 4767.170 | 358.534 | 222.103  | 92.374   |
| 959.198  | 4794.852 | 275.114 | 703.929  | 238.191  |
| 325.058  | 4869.086 | 397.863 | 284.823  | 214.628  |
| 1263.339 | 4639.420 | 338.953 | 939.459  | 312.357  |
| 935.975  | 4869.086 | 359.971 | 1596.406 | 521.135  |
| 595.401  | 4974.107 | 209.752 | 1850.412 | 1221.136 |
| 182.352  | 4524.844 | 201.270 | 353.447  | 43.587   |
| 369.693  | 4689.023 | 186.182 | 306.030  | 60.963   |
| 182.851  | 4730.719 | 148.680 | 435.922  | 63.696   |
| 1174.616 | 4891.124 | 137.426 | 0.000    | 1858.966 |
| 441.369  | 3839.697 | 492.527 | 319.368  | 54.613   |
| 275.134  | 4697.466 | 178.559 | 268.039  | 46.358   |
| 903.285  | 4991.118 | 148.545 | 0.000    | 850.375  |
| 1363.950 | 4810.418 | 780.068 | 375.003  | 380.281  |
| 461.797  | 4665.528 | 320.799 | 337.926  | 92.534   |
| 475.071  | 4965.520 | 258.809 | 101.911  | 251.876  |
| 585.587  | 4667.681 | 564.302 | 366.477  | 162.029  |
| 214.887  | 4771.159 | 271.691 | 303.261  | 92.735   |
| 500.253  | 5058.683 | 453.616 | -518.623 | 571.843  |
| 274.971  | 4562.578 | 483.355 | 327.836  | 95.648   |
| 723.021  | 4921.737 | 738.260 | 151.053  | 397.099  |
| 301.366  | 4712.115 | 395.518 | 330.543  | 116.271  |
| 556.249  | 4846.679 | 542.777 | 312.718  | 273.158  |
| 511.031  | 4859.795 | 253.775 | 526.503  | 209.876  |
| 836.932  | 4902.008 | 118.046 | 618.570  | 169.432  |
| 745.232  | 4935.904 | 103.849 | 763.448  | 203.842  |
| 1367.144 | 4967.242 | 204.463 | 261.000  | 325.582  |
| 194.097  | 4812.351 | 155.866 | 491.381  | 97.800   |
| 1819.816 | 4854.190 | 216.307 | 2329.268 | 902.691  |
| 251.333  | 4916.385 | 98.698  | 2274.218 | 229.987  |
| 959.108  | 4928.839 | 220.694 | 1586.692 | 460.118  |
| 1877.828 | 4963.796 | 90.360  | #VALUE!  | #VALUE!  |
| 380.313  | 4837.232 | 198.878 | 296.440  | 95.726   |
| 556.890  | 4779.104 | 336.650 | 344.135  | 135.272  |
| 560.310  | 4992.807 | 94.988  | 1167.503 | 314.074  |
| 656.056  | 4912.805 | 123.593 | 515.254  | 155.283  |
| 2863.207 | 4859.795 | 209.365 | 1968.621 | 1082.343 |
| 290.284  | 4968.962 | 108.152 | 994.687  | 254.744  |
| 888.447  | 4775.137 | 198.413 | 423.259  | 129.745  |
| 466.649  | 4874.629 | 182.641 | 363.894  | 131.128  |
| 1412.676 | 4898.390 | 143.155 | 1994.055 | 572.291  |
| 321.217  | 4726.607 | 196.378 | 322.072  | 65.218   |
| 554.742  | 4854.190 | 133.602 | 443.899  | 110.438  |
| 369.004  | 4846.679 | 172.412 | 278.055  | 83.652   |
| 658.455  | 4823.892 | 206.646 | 516.189  | 149.140  |
| 499.818  | 4889.301 | 106.289 | 755.601  | 144.969  |
| 507.560  | 4912.805 | 142.131 | 412.261  | 149.142  |
| 652.621  | 4962.070 | 102.497 | 1557.591 | 303.804  |

|          |          |         |           |           |
|----------|----------|---------|-----------|-----------|
| 320.829  | 4876.472 | 176.182 | 372.455   | 126.852   |
| 506.738  | 4937.664 | 97.655  | 842.833   | 187.630   |
| 485.715  | 4975.818 | 131.730 | 1227.460  | 338.128   |
| 262.338  | 4975.818 | 149.694 | 281.068   | 285.428   |
| 247.397  | 4902.008 | 118.046 | 547.157   | 132.688   |
|          |          |         |           |           |
| 523.870  | 4903.814 | 341.405 | 1521.680  | 535.476   |
| 434.907  | 4939.422 | 402.471 | 465.050   | 525.907   |
| 930.972  | 4887.476 | 250.319 | #VALUE!   | #VALUE!   |
| 1398.005 | 4956.877 | 664.947 | 200.911   | 747.813   |
| 596.168  | 5088.870 | 678.516 | -9576.750 | 10702.179 |
| 837.397  | 4617.270 | 342.549 | 471.613   | 137.189   |
| 449.205  | 4986.038 | 262.110 | 86.062    | 498.014   |
| 318.298  | 4718.345 | 401.127 | 372.530   | 135.895   |
| 318.395  | 4714.195 | 320.184 | 411.601   | 118.431   |
| 991.881  | 4932.376 | 318.218 | 385.601   | 366.103   |
| 1059.795 | 4925.292 | 356.193 | 1236.119  | 615.626   |
| 408.499  | 4887.476 | 300.383 | 978.164   | 371.950   |
| 363.064  | 4987.733 | 154.751 | -286.523  | 1020.538  |
| 404.308  | 4962.070 | 385.872 | 57.655    | 226.222   |
| 766.042  | 4905.617 | 452.731 | 407.501   | 411.383   |
| 444.000  | 4767.170 | 511.242 | 874.842   | 375.637   |
| 446.344  | 4810.418 | 526.546 | 371.627   | 248.348   |
| 491.920  | 4977.527 | 466.643 | 49.873    | 516.650   |
| 308.310  | 4909.216 | 390.013 | 227.287   | 247.916   |
| 452.965  | 4165.438 | 578.777 | 334.706   | 68.532    |
| 307.658  | 4481.095 | 182.591 | 340.244   | 43.587    |
| 579.110  | 4934.141 | 513.591 | 135.552   | 303.410   |
| 437.473  | 4541.482 | 384.621 | 335.078   | 80.925    |
| 534.843  | 4970.679 | 402.217 | 340.959   | 704.188   |
| 679.319  | 4842.908 | 262.298 | 820.106   | 268.033   |



| Sample   | $^{207}\text{Pb}/^{235}\text{U}$ | Error $2\sigma$ | $^{206}\text{Pb}/^{238}\text{U}$ | Error $2\sigma$ | rrelation_6_38 | $^{238}\text{U}/^{206}\text{Pb}$ |
|----------|----------------------------------|-----------------|----------------------------------|-----------------|----------------|----------------------------------|
| R_R19_1  | 0.680                            | 0.120           | 0.088                            | 0.005           | 0.244          | 11.429                           |
| R_R19_2  | 0.970                            | 0.150           | 0.094                            | 0.005           | -0.098         | 10.616                           |
| R_R19_3  | 0.760                            | 0.120           | 0.087                            | 0.005           | 0.216          | 11.494                           |
| R_R19_4  | 0.880                            | 0.100           | 0.079                            | 0.003           | 0.261          | 12.674                           |
| R_R19_5  | 1.300                            | 1.000           | 0.084                            | 0.005           | 0.005          | 11.862                           |
| R_R19_6  | 0.680                            | 0.130           | 0.080                            | 0.004           | 0.937          | 12.563                           |
| R_R19_7  | 1.050                            | 0.580           | 0.087                            | 0.006           | -0.036         | 11.547                           |
| R_R19_8  | 1.200                            | 1.100           | 0.087                            | 0.013           | 0.428          | 11.494                           |
| R_R19_9  | 0.600                            | 0.110           | 0.086                            | 0.004           | 0.672          | 11.574                           |
| R_R19_10 | 0.672                            | 0.094           | 0.077                            | 0.004           | 0.247          | 13.072                           |
| R_R19_11 | 6.900                            | 6.300           | 0.084                            | 0.011           | 0.889          | 11.905                           |
| R_R19_12 | 0.649                            | 0.089           | 0.076                            | 0.003           | -0.043         | 13.245                           |
| R_R19_13 | 1.230                            | 0.680           | 0.079                            | 0.003           | 0.219          | 12.723                           |
| R_R19_14 | 0.940                            | 0.360           | 0.085                            | 0.004           | 0.661          | 11.792                           |
| R_R19_16 | 0.614                            | 0.085           | 0.084                            | 0.002           | 0.030          | 11.976                           |
| R_R19_18 | 1.310                            | 0.950           | 0.084                            | 0.009           | 0.067          | 11.905                           |
| X73__1   | 100.000                          | 17.000          | 0.850                            | 0.140           | 0.968          | 1.176                            |
| X73__2   | 168.000                          | 10.000          | 1.480                            | 0.100           | 0.949          | 0.676                            |
| X73__3   | 121.500                          | 5.800           | 1.090                            | 0.049           | 0.646          | 0.917                            |
| X73__4   | 112.000                          | 5.300           | 0.974                            | 0.045           | 0.908          | 1.027                            |
| X73__5   | 224.900                          | 9.700           | 1.946                            | 0.098           | 0.893          | 0.514                            |
| X73__6   | 253.000                          | 22.000          | 2.320                            | 0.200           | 0.073          | 0.431                            |
| X73__7   | 3.720                            | 0.700           | 0.040                            | 0.006           | 0.916          | 24.752                           |
| X73__8   | 64.500                           | 3.800           | 0.575                            | 0.029           | 0.889          | 1.739                            |
| X73__9   | 204.000                          | 30.000          | 1.860                            | 0.280           | 0.979          | 0.538                            |
| X73__10  | 110.900                          | 4.000           | 0.959                            | 0.030           | 0.740          | 1.043                            |
| X73__11  | 291.000                          | 13.000          | 2.520                            | 0.110           | 0.861          | 0.397                            |
| X73__12  | 117.300                          | 5.200           | 1.041                            | 0.042           | 0.943          | 0.961                            |
| X73__13  | 249.000                          | 14.000          | 2.210                            | 0.130           | 0.971          | 0.452                            |
| X73__14  | 136.500                          | 5.500           | 1.196                            | 0.047           | 0.950          | 0.836                            |
| X73__15  | 336.000                          | 11.000          | 2.937                            | 0.096           | 0.869          | 0.340                            |
| X73__16  | 300.000                          | 17.000          | 2.600                            | 0.130           | 0.919          | 0.385                            |
| X73__17  | 176.000                          | 14.000          | 1.560                            | 0.120           | 0.972          | 0.641                            |
| X73__18  | 167.000                          | 8.900           | 1.418                            | 0.084           | 0.916          | 0.705                            |
| X73__19  | 192.500                          | 9.500           | 1.648                            | 0.081           | 0.866          | 0.607                            |
| X73__20  | 209.000                          | 12.000          | 1.828                            | 0.095           | 0.151          | 0.547                            |
| X73__21  | 219.000                          | 12.000          | 1.902                            | 0.094           | 0.951          | 0.526                            |
| X73__22  | 271.000                          | 11.000          | 2.390                            | 0.110           | 0.546          | 0.418                            |
| X73__23  | 478.000                          | 42.000          | 4.220                            | 0.370           | 0.975          | 0.237                            |
| X73__24  | 271.000                          | 11.000          | 2.260                            | 0.200           | 0.761          | 0.442                            |
| X73__25  | 244.000                          | 24.000          | 2.140                            | 0.220           | 1.000          | 0.467                            |
| X73__26  | 190.000                          | 11.000          | 1.720                            | 0.120           | 0.767          | 0.581                            |
| X73__27  | 188.000                          | 16.000          | 1.620                            | 0.110           | 0.495          | 0.617                            |
| X73__28  | 170.400                          | 6.200           | 1.485                            | 0.060           | 0.862          | 0.673                            |
| X73__29  | 154.600                          | 9.000           | 1.387                            | 0.053           | 0.625          | 0.721                            |
| X73__30  | 73.700                           | 7.000           | 0.627                            | 0.056           | 0.920          | 1.595                            |
| X73__31  | 250.000                          | 17.000          | 2.220                            | 0.150           | 0.926          | 0.450                            |
| X73__32  | 155.000                          | 12.000          | 1.810                            | 0.670           | 0.583          | 0.552                            |

|         |         |        |       |       |       |       |
|---------|---------|--------|-------|-------|-------|-------|
| X73__33 | 289.000 | 19.000 | 2.510 | 0.160 | 0.935 | 0.398 |
| X73__34 | 180.000 | 10.000 | 1.571 | 0.087 | 0.856 | 0.637 |
| X73__35 | 183.000 | 16.000 | 1.550 | 0.140 | 0.953 | 0.645 |
| X73__36 | 374.000 | 16.000 | 3.240 | 0.150 | 0.909 | 0.309 |
| X73__37 | 296.000 | 15.000 | 2.560 | 0.130 | 0.857 | 0.391 |
| X73__38 | 207.500 | 8.800  | 1.858 | 0.079 | 0.432 | 0.538 |
| X73__39 | 76.200  | 5.300  | 0.701 | 0.053 | 0.882 | 1.427 |
| X73__40 | 9.500   | 1.300  | 0.117 | 0.013 | 0.757 | 8.547 |
| X73__41 | 37.400  | 7.600  | 0.364 | 0.061 | 0.961 | 2.747 |
| X73__42 | 23.600  | 2.900  | 0.223 | 0.021 | 0.782 | 4.484 |
| X73__43 | 13.400  | 1.100  | 0.142 | 0.008 | 0.828 | 7.057 |
| X73__44 | 95.800  | 3.300  | 0.877 | 0.030 | 0.672 | 1.140 |
| X73__45 | 99.000  | 9.000  | 0.863 | 0.075 | 0.963 | 1.159 |
| X73__46 | 167.000 | 16.000 | 1.520 | 0.150 | 0.965 | 0.658 |
| X73__47 | 104.300 | 4.600  | 0.894 | 0.038 | 0.901 | 1.119 |
| X73__48 | 103.500 | 4.700  | 0.924 | 0.051 | 0.637 | 1.082 |
| X73__49 | 456.000 | 32.000 | 3.910 | 0.260 | 0.909 | 0.256 |
| X73__50 | 354.000 | 15.000 | 3.030 | 0.150 | 0.931 | 0.330 |
| X79__1  | 35.400  | 2.900  | 0.322 | 0.027 | 0.973 | 3.106 |
| X79__2  | 272.000 | 22.000 | 2.320 | 0.190 | 0.987 | 0.431 |
| X79__3  | 37.100  | 3.900  | 0.345 | 0.036 | 0.950 | 2.899 |
| X79__4  | 23.900  | 2.900  | 0.222 | 0.024 | 0.963 | 4.505 |
| X79__5  | 51.500  | 3.700  | 0.463 | 0.032 | 0.761 | 2.160 |
| X79__6  | 82.300  | 4.600  | 0.726 | 0.038 | 0.152 | 1.377 |
| X79__7  | 72.900  | 4.600  | 0.678 | 0.055 | 0.349 | 1.475 |
| X79__8  | 125.800 | 6.100  | 1.116 | 0.052 | 0.769 | 0.896 |
| X79__9  | 98.300  | 9.100  | 0.872 | 0.080 | 0.938 | 1.147 |
| X79__10 | 183.000 | 6.100  | 1.589 | 0.052 | 0.934 | 0.629 |
| X79__11 | 303.000 | 19.000 | 2.570 | 0.150 | 0.987 | 0.389 |
| X79__12 | 123.800 | 9.500  | 1.079 | 0.083 | 0.930 | 0.927 |
| X79__13 | 193.000 | 11.000 | 1.703 | 0.092 | 0.956 | 0.587 |
| X79__14 | 140.000 | 8.000  | 1.217 | 0.070 | 0.913 | 0.822 |
| X79__15 | 132.900 | 5.600  | 1.172 | 0.047 | 0.855 | 0.853 |
| X79__16 | 135.300 | 6.800  | 1.177 | 0.066 | 0.872 | 0.850 |
| X79__17 | 192.000 | 11.000 | 1.685 | 0.098 | 0.145 | 0.593 |
| X79__18 | 130.300 | 8.100  | 1.113 | 0.070 | 0.896 | 0.898 |
| X79__19 | 81.700  | 3.300  | 0.701 | 0.030 | 0.755 | 1.427 |
| X79__20 | 142.400 | 7.600  | 1.227 | 0.069 | 0.904 | 0.815 |
| X79__21 | 124.500 | 8.400  | 1.108 | 0.072 | 0.899 | 0.903 |
| X79__22 | 152.700 | 8.600  | 1.328 | 0.065 | 0.930 | 0.753 |
| X79__23 | 236.200 | 8.400  | 2.038 | 0.081 | 0.807 | 0.491 |
| X79__24 | 45.900  | 7.500  | 0.422 | 0.073 | 0.982 | 2.370 |
| X79__25 | 143.600 | 5.300  | 1.226 | 0.052 | 0.652 | 0.816 |
| X79__26 | 148.100 | 5.800  | 1.295 | 0.055 | 0.885 | 0.772 |
| X79__27 | 199.000 | 14.000 | 1.740 | 0.120 | 0.932 | 0.575 |
| X79__28 | 461.000 | 47.000 | 3.840 | 0.370 | 0.986 | 0.260 |
| X79__29 | 676.000 | 56.000 | 5.730 | 0.480 | 0.992 | 0.175 |
| X79__30 | 117.000 | 13.000 | 1.090 | 0.130 | 0.293 | 0.917 |
| X79__31 | 143.000 | 15.000 | 1.210 | 0.120 | 0.925 | 0.826 |

|          |         |        |       |       |        |        |
|----------|---------|--------|-------|-------|--------|--------|
| X79__32  | 161.300 | 8.100  | 1.490 | 0.120 | 0.240  | 0.671  |
| X79__33  | 180.000 | 40.000 | 1.400 | 0.290 | 0.993  | 0.714  |
| X79__34  | 325.000 | 15.000 | 2.770 | 0.140 | 0.922  | 0.361  |
| X79__35  | 170.000 | 12.000 | 1.450 | 0.100 | 0.984  | 0.690  |
| X79__36  | 174.700 | 7.500  | 1.482 | 0.063 | -0.097 | 0.675  |
| X79__37  | 152.000 | 31.000 | 1.320 | 0.280 | 0.994  | 0.758  |
| X79__38  | 170.600 | 9.300  | 1.497 | 0.049 | 0.987  | 0.668  |
| X79__39  | 130.800 | 9.400  | 1.088 | 0.092 | 0.439  | 0.919  |
| X79__40  | 180.000 | 14.000 | 1.540 | 0.120 | 0.991  | 0.649  |
| X79__41  | 685.000 | 47.000 | 5.900 | 0.420 | 0.990  | 0.169  |
| X79__42  | 448.000 | 50.000 | 3.700 | 0.380 | 0.982  | 0.270  |
| X79__43  | 134.100 | 6.200  | 1.172 | 0.081 | 0.307  | 0.853  |
| X79__44  | 337.000 | 26.000 | 2.820 | 0.200 | 0.964  | 0.355  |
| X79__45  | 119.000 | 15.000 | 1.050 | 0.130 | 0.995  | 0.952  |
| X79__46  | 81.300  | 3.100  | 0.719 | 0.031 | 0.653  | 1.391  |
| X79__47  | 133.700 | 6.300  | 1.143 | 0.062 | 0.866  | 0.875  |
| X79__48  | 315.000 | 24.000 | 2.810 | 0.210 | 0.961  | 0.356  |
| X79__49  | 105.000 | 14.000 | 0.920 | 0.110 | 0.978  | 1.087  |
| X79__50  | 182.000 | 8.100  | 1.547 | 0.077 | 0.925  | 0.646  |
| X79__51  | 104.300 | 4.600  | 0.933 | 0.045 | 0.863  | 1.072  |
| X79__52  | 81.600  | 6.700  | 0.727 | 0.061 | 0.963  | 1.376  |
| X79__53  | 364.000 | 25.000 | 3.110 | 0.200 | 0.943  | 0.322  |
| X79__54  | 994.000 | 59.000 | 8.730 | 0.560 | 0.951  | 0.115  |
| X79__55  | 880.000 | 54.000 | 7.360 | 0.460 | 0.949  | 0.136  |
| X79__56  | 417.000 | 21.000 | 3.660 | 0.190 | 0.935  | 0.273  |
| X79__57  | 484.000 | 36.000 | 4.060 | 0.280 | 0.965  | 0.246  |
| X79__58  | 215.000 | 15.000 | 1.850 | 0.120 | 0.931  | 0.541  |
| X79__59  | 215.000 | 11.000 | 1.880 | 0.100 | 0.780  | 0.532  |
|          |         |        |       |       |        |        |
| X128__1  | 65.000  | 14.000 | 0.570 | 0.110 | 0.983  | 1.754  |
| X128__2  | 29.700  | 6.600  | 0.263 | 0.057 | 0.994  | 3.802  |
| X128__3  | 131.000 | 34.000 | 1.180 | 0.300 | 0.994  | 0.847  |
| X128__4  | 88.800  | 6.700  | 0.778 | 0.056 | 0.932  | 1.285  |
| X128__5  | 405.000 | 58.000 | 3.720 | 0.530 | 0.066  | 0.269  |
| X128__6  | 7.550   | 0.950  | 0.098 | 0.009 | 0.985  | 10.194 |
| X128__7  | 5.600   | 0.570  | 0.058 | 0.005 | 0.443  | 17.271 |
| X128__8  | 16.500  | 1.200  | 0.152 | 0.011 | 0.544  | 6.579  |
| X128__9  | 9.400   | 2.000  | 0.083 | 0.018 | 0.763  | 12.048 |
| X128__10 | 2.580   | 0.390  | 0.040 | 0.003 | 0.912  | 25.126 |
| X128__11 | 6.490   | 0.640  | 0.083 | 0.008 | -0.079 | 12.107 |
| X128__12 | 17.100  | 1.400  | 0.220 | 0.120 | -0.016 | 4.545  |
| X128__13 | 14.900  | 1.800  | 0.157 | 0.016 | 0.920  | 6.369  |
| X128__14 | 14.700  | 2.000  | 0.148 | 0.027 | 0.406  | 6.757  |
| X128__15 | 104.000 | 36.000 | 0.800 | 0.260 | 0.990  | 1.250  |
| X128__16 | 9.300   | 1.100  | 0.093 | 0.011 | 0.919  | 10.753 |
| X128__17 | 11.000  | 1.200  | 0.094 | 0.011 | 0.421  | 10.638 |
| X128__18 | 46.400  | 5.400  | 0.432 | 0.056 | 0.622  | 2.315  |
| X128__19 | 5.730   | 0.340  | 0.067 | 0.003 | 0.701  | 14.925 |
| X128__20 | 3.770   | 0.280  | 0.043 | 0.001 | -0.116 | 23.529 |
| X128__21 | 8.320   | 0.860  | 0.075 | 0.007 | 0.471  | 13.263 |



|          |         |        |       |       |        |        |
|----------|---------|--------|-------|-------|--------|--------|
| X128__22 | 10.210  | 0.920  | 0.106 | 0.007 | 0.346  | 9.425  |
| X128__23 | 9.390   | 0.440  | 0.092 | 0.004 | 0.768  | 10.881 |
| X128__24 | 12.560  | 0.720  | 0.124 | 0.007 | 0.800  | 8.045  |
| X128__25 | 15.200  | 1.100  | 0.151 | 0.009 | 0.913  | 6.636  |
| X128__26 | 38.900  | 3.600  | 0.360 | 0.034 | 0.923  | 2.778  |
| X128__27 | 17.220  | 0.680  | 0.171 | 0.005 | -0.030 | 5.851  |
| X128__28 | 14.170  | 0.840  | 0.150 | 0.007 | 0.476  | 6.662  |
| X128__29 | 5.220   | 0.440  | 0.053 | 0.004 | 0.589  | 18.727 |
| X128__30 | 106.000 | 24.000 | 0.950 | 0.210 | 0.992  | 1.053  |
| X128__31 | 3.670   | 0.370  | 0.040 | 0.004 | 0.795  | 25.063 |
| X128__32 | 9.470   | 0.590  | 0.095 | 0.005 | 0.770  | 10.549 |
| X128__33 | 22.400  | 2.500  | 0.211 | 0.019 | 0.791  | 4.739  |
| X128__34 | 13.000  | 1.800  | 0.119 | 0.017 | 0.968  | 8.403  |
| X128__35 | 7.500   | 1.700  | 0.083 | 0.015 | 0.981  | 12.048 |
| X128__36 | 7.040   | 0.530  | 0.083 | 0.004 | 0.099  | 12.019 |
| X128__37 | 11.500  | 1.100  | 0.119 | 0.011 | 0.761  | 8.403  |
| X128__38 | 52.700  | 5.000  | 0.456 | 0.050 | 0.360  | 2.193  |
| X128__39 | 6.090   | 0.390  | 0.062 | 0.003 | 0.476  | 16.026 |
| X128__40 | 336.000 | 43.000 | 2.840 | 0.370 | 0.993  | 0.352  |
| X128__41 | 52.500  | 5.700  | 0.455 | 0.044 | 0.965  | 2.198  |
| X128__42 | 76.100  | 6.800  | 0.667 | 0.062 | 0.948  | 1.499  |
| X128__43 | 48.600  | 4.800  | 0.428 | 0.042 | -0.013 | 2.336  |
| X128__44 | 7.250   | 0.610  | 0.077 | 0.008 | 0.571  | 12.920 |
| X128__45 | 8.320   | 0.500  | 0.080 | 0.004 | 0.139  | 12.484 |
| X128__46 | 8.600   | 0.590  | 0.081 | 0.005 | 0.591  | 12.285 |
| X128__47 | 95.300  | 5.800  | 0.841 | 0.052 | 0.956  | 1.189  |
| X128__48 | 21.580  | 0.790  | 0.220 | 0.009 | 0.115  | 4.554  |
| X128__49 | 12.100  | 0.860  | 0.137 | 0.008 | 0.502  | 7.321  |
| X128__50 | 78.500  | 5.400  | 0.703 | 0.046 | 0.931  | 1.422  |
| X128__51 | 19.800  | 1.100  | 0.205 | 0.025 | 0.004  | 4.878  |
| X128__52 | 11.100  | 1.500  | 0.135 | 0.015 | 0.968  | 7.407  |
| X128__53 | 9.350   | 0.580  | 0.108 | 0.005 | -0.435 | 9.268  |
| X128__54 | 9.250   | 0.330  | 0.116 | 0.004 | 0.841  | 8.621  |
| X128__55 | 4.890   | 0.690  | 0.051 | 0.006 | 0.024  | 19.646 |
| X128__56 | 10.450  | 0.570  | 0.109 | 0.005 | 0.387  | 9.158  |
| X128__57 | 9.220   | 0.440  | 0.118 | 0.005 | 0.689  | 8.503  |
| X128__58 | 59.800  | 4.700  | 0.534 | 0.049 | 0.178  | 1.873  |
| X128__59 | 131.000 | 12.000 | 1.102 | 0.093 | 0.140  | 0.907  |
| X128__60 | 25.100  | 3.300  | 0.246 | 0.027 | 0.769  | 4.065  |
| X128__61 | 7.140   | 0.500  | 0.068 | 0.005 | 0.383  | 14.706 |
| X128__62 | 8.740   | 0.540  | 0.092 | 0.005 | 0.839  | 10.881 |
| X128__63 | 4.600   | 0.350  | 0.044 | 0.005 | -0.025 | 22.831 |
| X128__64 | 16.800  | 1.300  | 0.158 | 0.013 | 0.879  | 6.329  |
| X128__65 | 3.300   | 2.500  | 0.022 | 0.002 | 0.292  | 44.643 |
| X128__66 | 3.350   | 0.350  | 0.036 | 0.003 | -0.036 | 28.011 |
| X128__67 | 7.290   | 0.410  | 0.073 | 0.004 | 0.277  | 13.793 |
| X128__68 | 3.750   | 0.490  | 0.051 | 0.025 | 0.034  | 19.608 |
| X128__69 | 24.500  | 1.600  | 0.218 | 0.012 | 0.801  | 4.587  |
| X128__70 | 362.000 | 16.000 | 3.190 | 0.160 | 0.305  | 0.313  |
| X128__71 | 4.550   | 0.440  | 0.072 | 0.005 | 0.907  | 13.870 |

|          |        |       |       |       |       |        |
|----------|--------|-------|-------|-------|-------|--------|
| X128__72 | 10.790 | 0.860 | 0.122 | 0.007 | 0.807 | 8.183  |
| X128__73 | 9.270  | 0.640 | 0.116 | 0.006 | 0.867 | 8.621  |
| X128__74 | 9.550  | 0.490 | 0.122 | 0.006 | 0.353 | 8.197  |
| X128__75 | 9.000  | 0.790 | 0.101 | 0.008 | 0.975 | 9.940  |
| X128__76 | 10.230 | 0.900 | 0.115 | 0.006 | 0.609 | 8.688  |
| X128__77 | 6.220  | 0.500 | 0.071 | 0.005 | 0.385 | 14.104 |
| X128__78 | 4.000  | 0.290 | 0.055 | 0.003 | 0.161 | 18.282 |
| X128__79 | 25.400 | 1.400 | 0.239 | 0.013 | 0.333 | 4.184  |
| X128__80 | 15.000 | 1.000 | 0.145 | 0.009 | 0.604 | 6.878  |





| Error 2σ | <sup>207</sup> Pb/ <sup>206</sup> Pb | Error 2σ | Correlation_38_ | FinalAge <sup>206</sup> Pb/ <sup>23</sup> | Error 2σ | FinalAge <sup>207</sup> Pb |
|----------|--------------------------------------|----------|-----------------|-------------------------------------------|----------|----------------------------|
| 0.679    | 0.058                                | 0.010    | 0.037           | 540.735                                   | 32.135   | 526.774                    |
| 0.507    | 0.079                                | 0.015    | 0.081           | 580.329                                   | 27.723   | 688.464                    |
| 0.674    | 0.062                                | 0.011    | 0.154           | 537.770                                   | 31.524   | 574.010                    |
| 0.466    | 0.077                                | 0.008    | 0.072           | 489.554                                   | 17.994   | 640.983                    |
| 0.746    | 0.106                                | 0.092    | 0.095           | 521.738                                   | 32.802   | 845.722                    |
| 0.616    | 0.058                                | 0.010    | 0.210           | 493.735                                   | 24.191   | 526.774                    |
| 0.760    | 0.090                                | 0.052    | 0.039           | 535.398                                   | 35.240   | 728.882                    |
| 1.718    | 0.130                                | 0.110    | 0.002           | 537.770                                   | 80.356   | 800.586                    |
| 0.509    | 0.052                                | 0.010    | -0.424          | 534.211                                   | 23.495   | 477.234                    |
| 0.701    | 0.064                                | 0.009    | -0.210          | 475.198                                   | 25.468   | 521.928                    |
| 1.559    | 0.180                                | 0.150    | -0.168          | 519.954                                   | 68.089   | 2098.657                   |
| 0.579    | 0.062                                | 0.009    | 0.217           | 469.207                                   | 20.508   | 507.863                    |
| 0.534    | 0.089                                | 0.041    | 0.095           | 487.761                                   | 20.479   | 814.339                    |
| 0.612    | 0.083                                | 0.035    | -0.362          | 524.710                                   | 27.226   | 672.882                    |
| 0.301    | 0.052                                | 0.007    | -0.032          | 516.980                                   | 13.002   | 486.080                    |
| 1.219    | 0.074                                | 0.026    | -0.024          | 519.954                                   | 53.233   | 850.127                    |
| 0.194    | 0.822                                | 0.023    | 0.002           | 3965.741                                  | 653.181  | 4686.115                   |
| 0.046    | 0.828                                | 0.015    | 0.333           | 5855.011                                  | 395.609  | 5208.812                   |
| 0.041    | 0.822                                | 0.021    | 0.306           | 4752.065                                  | 213.625  | 4882.074                   |
| 0.047    | 0.836                                | 0.017    | 0.096           | 4383.961                                  | 202.544  | 4800.109                   |
| 0.026    | 0.828                                | 0.018    | 0.412           | 6965.017                                  | 350.756  | 5503.470                   |
| 0.037    | 0.834                                | 0.043    | 0.366           | 7735.470                                  | 666.851  | 5622.515                   |
| 3.431    | 0.661                                | 0.063    | -0.390          | 255.312                                   | 35.390   | 1575.680                   |
| 0.088    | 0.828                                | 0.022    | 0.168           | 2928.318                                  | 147.689  | 4246.383                   |
| 0.081    | 0.821                                | 0.025    | -0.017          | 6774.031                                  | 1019.747 | 5404.894                   |
| 0.033    | 0.835                                | 0.021    | 0.176           | 4334.789                                  | 135.603  | 4790.177                   |
| 0.017    | 0.842                                | 0.017    | 0.328           | 8112.561                                  | 354.120  | 5764.080                   |
| 0.039    | 0.820                                | 0.017    | 0.063           | 4599.129                                  | 185.556  | 4846.651                   |
| 0.027    | 0.819                                | 0.012    | 0.255           | 7518.266                                  | 442.251  | 5606.398                   |
| 0.033    | 0.825                                | 0.014    | -0.199          | 5070.991                                  | 199.278  | 4999.364                   |
| 0.011    | 0.832                                | 0.011    | 0.320           | 8834.289                                  | 288.761  | 5909.614                   |
| 0.019    | 0.821                                | 0.015    | 0.120           | 8257.430                                  | 412.872  | 5794.903                   |
| 0.049    | 0.832                                | 0.015    | 0.103           | 6059.676                                  | 466.129  | 5255.775                   |
| 0.042    | 0.835                                | 0.019    | 0.393           | 5691.802                                  | 337.173  | 5202.786                   |
| 0.030    | 0.817                                | 0.021    | 0.120           | 6277.548                                  | 308.545  | 5346.274                   |
| 0.028    | 0.816                                | 0.024    | 0.045           | 6701.497                                  | 348.273  | 5429.362                   |
| 0.026    | 0.826                                | 0.014    | 0.105           | 6868.011                                  | 339.428  | 5476.598                   |
| 0.019    | 0.839                                | 0.022    | 0.503           | 7869.975                                  | 362.216  | 5692.036                   |
| 0.021    | 0.821                                | 0.012    | 0.072           | 10652.683                                 | 934.003  | 6266.640                   |
| 0.039    | 0.830                                | 0.016    | 0.028           | 7617.903                                  | 674.151  | 5692.036                   |
| 0.048    | 0.841                                | 0.020    | 0.245           | 7376.134                                  | 758.294  | 5585.884                   |
| 0.041    | 0.820                                | 0.022    | 0.535           | 6450.488                                  | 450.034  | 5333.069                   |
| 0.042    | 0.815                                | 0.027    | -0.292          | 6209.021                                  | 421.600  | 5322.381                   |
| 0.027    | 0.828                                | 0.019    | 0.432           | 5867.995                                  | 237.091  | 5223.130                   |
| 0.028    | 0.830                                | 0.025    | -0.040          | 5608.621                                  | 214.316  | 5124.931                   |
| 0.142    | 0.818                                | 0.030    | 0.329           | 3137.714                                  | 280.242  | 4379.835                   |
| 0.030    | 0.838                                | 0.023    | 0.295           | 7538.317                                  | 509.346  | 5610.451                   |
| 0.205    | 0.820                                | 0.025    | 0.700           | 6660.335                                  | 2465.428 | 5127.538                   |

|       |       |       |        |           |          |          |
|-------|-------|-------|--------|-----------|----------|----------|
| 0.025 | 0.833 | 0.020 | 0.054  | 8094.221  | 515.966  | 5757.101 |
| 0.035 | 0.829 | 0.025 | 0.310  | 6087.316  | 337.108  | 5278.466 |
| 0.058 | 0.844 | 0.020 | 0.201  | 6034.446  | 545.047  | 5295.157 |
| 0.014 | 0.843 | 0.016 | 0.234  | 9312.253  | 431.123  | 6018.100 |
| 0.020 | 0.831 | 0.022 | 0.196  | 8185.402  | 415.665  | 5781.319 |
| 0.023 | 0.817 | 0.025 | 0.573  | 6769.522  | 287.832  | 5422.084 |
| 0.108 | 0.803 | 0.025 | 0.266  | 3424.440  | 258.909  | 4413.260 |
| 0.950 | 0.591 | 0.057 | 0.237  | 713.273   | 79.253   | 2387.547 |
| 0.460 | 0.775 | 0.047 | -0.285 | 2001.106  | 335.350  | 3704.176 |
| 0.422 | 0.764 | 0.047 | 0.235  | 1297.707  | 122.206  | 3252.014 |
| 0.418 | 0.660 | 0.032 | -0.286 | 854.268   | 50.641   | 2708.258 |
| 0.039 | 0.803 | 0.023 | 0.249  | 4059.144  | 138.853  | 4642.988 |
| 0.101 | 0.824 | 0.018 | 0.074  | 4010.882  | 348.570  | 4676.012 |
| 0.065 | 0.805 | 0.017 | 0.104  | 5958.156  | 587.976  | 5202.786 |
| 0.048 | 0.835 | 0.015 | 0.136  | 4117.267  | 175.007  | 4728.449 |
| 0.060 | 0.836 | 0.031 | 0.526  | 4218.574  | 232.843  | 4720.706 |
| 0.017 | 0.842 | 0.025 | 0.061  | 10258.011 | 682.118  | 6218.900 |
| 0.016 | 0.832 | 0.018 | 0.454  | 8984.795  | 444.792  | 5962.449 |
| 0.260 | 0.805 | 0.022 | 0.215  | 1799.489  | 150.889  | 3649.864 |
| 0.035 | 0.848 | 0.009 | 0.217  | 7735.470  | 633.508  | 5695.763 |
| 0.302 | 0.778 | 0.025 | -0.078 | 1910.679  | 199.375  | 3696.212 |
| 0.487 | 0.787 | 0.029 | -0.142 | 1292.434  | 139.723  | 3264.322 |
| 0.149 | 0.798 | 0.038 | 0.305  | 2452.790  | 169.523  | 4021.743 |
| 0.072 | 0.817 | 0.027 | 0.084  | 3518.495  | 184.164  | 4490.479 |
| 0.120 | 0.800 | 0.025 | 0.425  | 3336.681  | 270.675  | 4368.902 |
| 0.042 | 0.811 | 0.024 | 0.308  | 4831.765  | 225.136  | 4917.105 |
| 0.105 | 0.802 | 0.024 | 0.277  | 4041.949  | 370.821  | 4668.879 |
| 0.021 | 0.839 | 0.009 | 0.267  | 6132.291  | 200.679  | 5295.157 |
| 0.023 | 0.844 | 0.008 | -0.273 | 8203.485  | 478.803  | 5804.973 |
| 0.071 | 0.836 | 0.019 | 0.189  | 4718.047  | 362.927  | 4900.962 |
| 0.032 | 0.838 | 0.015 | -0.071 | 6410.071  | 346.287  | 5348.894 |
| 0.047 | 0.829 | 0.019 | 0.295  | 5132.344  | 295.205  | 5024.887 |
| 0.034 | 0.809 | 0.017 | 0.312  | 5000.151  | 200.518  | 4972.425 |
| 0.048 | 0.832 | 0.024 | 0.333  | 5014.974  | 281.213  | 4990.464 |
| 0.035 | 0.841 | 0.021 | 0.332  | 6366.999  | 370.306  | 5343.646 |
| 0.057 | 0.828 | 0.023 | 0.329  | 4822.619  | 303.309  | 4952.515 |
| 0.061 | 0.817 | 0.022 | 0.327  | 3424.440  | 146.552  | 4483.139 |
| 0.046 | 0.850 | 0.018 | 0.333  | 5161.356  | 290.247  | 5042.025 |
| 0.059 | 0.808 | 0.022 | 0.248  | 4807.347  | 312.391  | 4906.641 |
| 0.037 | 0.837 | 0.018 | -0.098 | 5447.281  | 266.621  | 5112.456 |
| 0.020 | 0.831 | 0.019 | 0.315  | 7163.252  | 284.702  | 5553.032 |
| 0.410 | 0.823 | 0.020 | 0.085  | 2269.552  | 392.600  | 3907.212 |
| 0.035 | 0.839 | 0.029 | 0.610  | 5158.461  | 218.793  | 5050.486 |
| 0.033 | 0.835 | 0.018 | 0.423  | 5355.248  | 227.443  | 5081.604 |
| 0.040 | 0.837 | 0.020 | 0.293  | 6497.714  | 448.118  | 5379.822 |
| 0.025 | 0.847 | 0.016 | -0.081 | 10165.445 | 979.483  | 6229.949 |
| 0.015 | 0.856 | 0.008 | 0.004  | 12290.573 | 1029.577 | 6617.933 |
| 0.109 | 0.834 | 0.028 | 0.195  | 4752.065  | 566.760  | 4844.072 |
| 0.082 | 0.846 | 0.019 | 0.281  | 5111.958  | 506.971  | 5046.264 |

|       |       |       |        |           |          |          |
|-------|-------|-------|--------|-----------|----------|----------|
| 0.054 | 0.838 | 0.024 | 0.580  | 5880.952  | 473.634  | 5167.738 |
| 0.148 | 0.868 | 0.026 | 0.057  | 5643.634  | 1169.038 | 5278.466 |
| 0.018 | 0.847 | 0.016 | 0.361  | 8554.875  | 432.376  | 5875.918 |
| 0.048 | 0.849 | 0.012 | -0.068 | 5776.555  | 398.383  | 5220.758 |
| 0.029 | 0.850 | 0.013 | 0.455  | 5860.207  | 249.118  | 5248.290 |
| 0.161 | 0.841 | 0.017 | -0.154 | 5425.091  | 1150.777 | 5107.821 |
| 0.022 | 0.842 | 0.014 | -0.271 | 5899.049  | 193.088  | 5224.315 |
| 0.078 | 0.852 | 0.018 | 0.226  | 4745.893  | 401.307  | 4956.375 |
| 0.051 | 0.848 | 0.008 | 0.150  | 6009.116  | 468.243  | 5278.466 |
| 0.012 | 0.843 | 0.009 | -0.062 | 12451.387 | 886.370  | 6631.342 |
| 0.028 | 0.851 | 0.015 | -0.142 | 9976.229  | 1024.586 | 6200.968 |
| 0.059 | 0.845 | 0.027 | 0.709  | 5000.151  | 345.574  | 4981.485 |
| 0.025 | 0.847 | 0.016 | -0.160 | 8639.809  | 612.752  | 5912.622 |
| 0.118 | 0.823 | 0.016 | -0.029 | 4627.493  | 572.928  | 4861.138 |
| 0.060 | 0.827 | 0.027 | 0.688  | 3492.298  | 150.572  | 4478.216 |
| 0.047 | 0.841 | 0.023 | 0.419  | 4913.500  | 266.524  | 4978.474 |
| 0.027 | 0.824 | 0.020 | 0.097  | 8622.912  | 644.417  | 5844.283 |
| 0.130 | 0.830 | 0.021 | -0.583 | 4205.158  | 502.791  | 4735.177 |
| 0.032 | 0.836 | 0.021 | 0.407  | 6026.857  | 299.979  | 5289.624 |
| 0.052 | 0.814 | 0.021 | 0.422  | 4248.659  | 204.919  | 4728.449 |
| 0.115 | 0.818 | 0.024 | 0.386  | 3522.229  | 295.538  | 4481.911 |
| 0.021 | 0.844 | 0.017 | -0.013 | 9111.510  | 585.949  | 5990.656 |
| 0.007 | 0.837 | 0.013 | 0.475  | 14666.971 | 940.837  | 7008.928 |
| 0.008 | 0.871 | 0.014 | 0.526  | 13688.693 | 855.543  | 6885.371 |
| 0.014 | 0.848 | 0.015 | 0.387  | 9921.131  | 515.031  | 6128.326 |
| 0.017 | 0.848 | 0.016 | 0.000  | 10452.000 | 720.828  | 6279.280 |
| 0.035 | 0.835 | 0.018 | 0.079  | 6751.452  | 437.932  | 5457.967 |
| 0.028 | 0.845 | 0.023 | 0.297  | 6818.954  | 362.710  | 5457.967 |
| 0.339 | 0.834 | 0.025 | -0.082 | 2907.820  | 561.158  | 4254.104 |
| 0.824 | 0.814 | 0.019 | 0.090  | 1505.172  | 326.216  | 3476.938 |
| 0.215 | 0.804 | 0.023 | 0.159  | 5023.851  | 1277.250 | 4957.914 |
| 0.093 | 0.812 | 0.022 | 0.181  | 3709.841  | 267.032  | 4566.772 |
| 0.038 | 0.795 | 0.049 | 0.145  | 10003.602 | 1425.244 | 6098.749 |
| 0.966 | 0.574 | 0.030 | -0.432 | 603.265   | 57.190   | 2178.942 |
| 1.491 | 0.698 | 0.065 | 0.331  | 362.842   | 31.333   | 1916.099 |
| 0.476 | 0.790 | 0.060 | 0.563  | 912.165   | 66.012   | 2906.230 |
| 2.613 | 0.806 | 0.038 | 0.086  | 514.005   | 111.471  | 2377.830 |
| 1.957 | 0.443 | 0.035 | -0.499 | 251.593   | 19.596   | 1294.982 |
| 1.099 | 0.578 | 0.034 | 0.420  | 511.623   | 46.455   | 2044.544 |
| 2.479 | 0.759 | 0.068 | -0.062 | 1281.875  | 699.205  | 2940.460 |
| 0.649 | 0.687 | 0.034 | -0.049 | 940.083   | 95.805   | 2808.874 |
| 1.233 | 0.777 | 0.038 | 0.428  | 889.742   | 162.318  | 2796.020 |
| 0.406 | 0.793 | 0.036 | -0.013 | 3789.116  | 1231.463 | 4725.552 |
| 1.272 | 0.740 | 0.048 | 0.340  | 573.255   | 67.804   | 2368.019 |
| 1.245 | 0.855 | 0.084 | 0.801  | 579.150   | 67.773   | 2523.132 |
| 0.300 | 0.820 | 0.090 | 0.576  | 2314.727  | 300.057  | 3917.980 |
| 0.735 | 0.630 | 0.024 | 0.159  | 418.056   | 20.591   | 1935.904 |
| 0.720 | 0.632 | 0.054 | 0.534  | 268.311   | 8.207    | 1586.380 |
| 1.214 | 0.814 | 0.087 | 0.556  | 468.607   | 42.883   | 2266.500 |

|       |       |       |        |          |          |          |
|-------|-------|-------|--------|----------|----------|----------|
| 0.657 | 0.687 | 0.055 | 0.175  | 650.058  | 45.339   | 2453.984 |
| 0.414 | 0.730 | 0.021 | 0.095  | 566.764  | 21.585   | 2376.853 |
| 0.440 | 0.743 | 0.031 | 0.193  | 755.266  | 41.318   | 2647.230 |
| 0.383 | 0.738 | 0.023 | -0.151 | 904.886  | 52.240   | 2827.853 |
| 0.262 | 0.802 | 0.023 | -0.077 | 1982.174 | 187.205  | 3743.084 |
| 0.164 | 0.727 | 0.025 | 0.173  | 1017.068 | 28.566   | 2947.170 |
| 0.302 | 0.686 | 0.028 | 0.066  | 901.524  | 40.842   | 2761.151 |
| 1.508 | 0.694 | 0.058 | 0.386  | 335.362  | 27.005   | 1855.887 |
| 0.233 | 0.841 | 0.018 | -0.056 | 4305.105 | 951.655  | 4744.711 |
| 2.261 | 0.653 | 0.053 | -0.159 | 252.213  | 22.756   | 1564.867 |
| 0.601 | 0.720 | 0.038 | 0.488  | 583.863  | 33.258   | 2384.641 |
| 0.427 | 0.775 | 0.049 | -0.042 | 1234.143 | 111.131  | 3201.235 |
| 1.200 | 0.790 | 0.031 | 0.076  | 724.805  | 103.544  | 2679.654 |
| 2.177 | 0.654 | 0.038 | -0.490 | 514.005  | 92.892   | 2172.987 |
| 0.592 | 0.608 | 0.053 | 0.555  | 515.195  | 25.388   | 2116.494 |
| 0.777 | 0.687 | 0.040 | 0.212  | 724.805  | 66.999   | 2564.582 |
| 0.240 | 0.870 | 0.035 | 0.387  | 2421.872 | 265.556  | 4044.690 |
| 0.770 | 0.697 | 0.039 | 0.239  | 390.205  | 18.760   | 1988.816 |
| 0.046 | 0.859 | 0.014 | 0.040  | 8673.472 | 1129.995 | 5909.614 |
| 0.213 | 0.815 | 0.019 | -0.133 | 2417.443 | 233.775  | 4040.901 |
| 0.139 | 0.825 | 0.026 | 0.064  | 3294.283 | 306.215  | 4411.944 |
| 0.229 | 0.831 | 0.022 | 0.371  | 2296.695 | 225.377  | 3964.046 |
| 1.319 | 0.671 | 0.072 | 0.449  | 480.585  | 49.052   | 2142.675 |
| 0.655 | 0.756 | 0.046 | 0.577  | 496.720  | 26.045   | 2266.500 |
| 0.800 | 0.751 | 0.039 | 0.418  | 504.474  | 32.847   | 2296.556 |
| 0.074 | 0.830 | 0.014 | 0.200  | 3934.304 | 243.263  | 4637.730 |
| 0.191 | 0.700 | 0.021 | 0.381  | 1279.761 | 53.615   | 3165.015 |
| 0.402 | 0.655 | 0.045 | 0.342  | 825.408  | 45.319   | 2612.187 |
| 0.093 | 0.808 | 0.018 | 0.177  | 3432.015 | 224.570  | 4443.070 |
| 0.595 | 0.717 | 0.047 | 0.018  | 1202.125 | 146.601  | 3081.640 |
| 0.823 | 0.604 | 0.020 | -0.357 | 816.327  | 90.703   | 2531.559 |
| 0.438 | 0.640 | 0.040 | 0.879  | 660.540  | 31.221   | 2372.937 |
| 0.312 | 0.588 | 0.010 | 0.745  | 707.500  | 25.616   | 2363.078 |
| 2.432 | 0.654 | 0.030 | 0.329  | 320.045  | 39.613   | 1800.534 |
| 0.453 | 0.708 | 0.032 | 0.143  | 668.100  | 33.038   | 2475.493 |
| 0.347 | 0.570 | 0.019 | -0.307 | 716.735  | 29.254   | 2360.102 |
| 0.172 | 0.819 | 0.027 | 0.069  | 2758.283 | 253.101  | 4170.777 |
| 0.077 | 0.845 | 0.021 | -0.084 | 4788.972 | 404.151  | 4957.914 |
| 0.446 | 0.757 | 0.067 | 0.513  | 1417.814 | 155.614  | 3312.114 |
| 1.146 | 0.768 | 0.071 | 0.683  | 424.095  | 33.054   | 2129.045 |
| 0.533 | 0.691 | 0.031 | 0.225  | 566.764  | 27.752   | 2311.257 |
| 2.658 | 0.760 | 0.080 | -0.041 | 276.344  | 32.177   | 1749.268 |
| 0.521 | 0.765 | 0.039 | 0.426  | 945.653  | 77.807   | 2923.489 |
| 3.388 | 0.682 | 0.095 | -0.156 | 142.806  | 10.838   | 1481.053 |
| 2.354 | 0.700 | 0.110 | 0.753  | 226.124  | 19.002   | 1492.792 |
| 0.685 | 0.726 | 0.043 | 0.444  | 451.200  | 22.404   | 2147.586 |
| 9.612 | 0.761 | 0.059 | 0.121  | 320.658  | 157.185  | 1582.114 |
| 0.253 | 0.820 | 0.030 | -0.110 | 1271.298 | 69.980   | 3288.499 |
| 0.016 | 0.843 | 0.015 | 0.607  | 9235.782 | 463.237  | 5985.077 |
| 0.943 | 0.456 | 0.018 | -0.237 | 448.795  | 30.501   | 1740.161 |



|       |       |       |        |          |        |          |
|-------|-------|-------|--------|----------|--------|----------|
| 0.469 | 0.630 | 0.029 | 0.105  | 743.214  | 42.574 | 2505.206 |
| 0.461 | 0.592 | 0.018 | -0.188 | 707.500  | 37.815 | 2365.058 |
| 0.383 | 0.571 | 0.019 | 0.372  | 742.065  | 34.670 | 2392.370 |
| 0.790 | 0.644 | 0.013 | -0.370 | 617.924  | 49.139 | 2338.006 |
| 0.438 | 0.654 | 0.051 | 0.300  | 702.299  | 35.390 | 2455.794 |
| 0.935 | 0.648 | 0.065 | 0.406  | 441.576  | 29.272 | 2007.265 |
| 0.836 | 0.553 | 0.050 | 0.313  | 343.313  | 15.691 | 1634.196 |
| 0.228 | 0.765 | 0.032 | 0.541  | 1381.496 | 75.144 | 3323.718 |
| 0.416 | 0.746 | 0.046 | 0.302  | 875.126  | 52.965 | 2815.240 |





| Error 2σ | FinalAge <sup>207</sup> Pb | Error 2σ | FinalAge <sup>207</sup> Pb corr | Error 2σ |
|----------|----------------------------|----------|---------------------------------|----------|
| 92.960   | 529.762                    | 91.338   | 540.924                         | 32.029   |
| 106.463  | 1172.135                   | 222.557  | 566.699                         | 28.373   |
| 90.633   | 674.109                    | 119.600  | 535.329                         | 31.437   |
| 72.839   | 1131.515                   | 122.800  | 477.481                         | 17.868   |
| 650.555  | 1731.725                   | 1503.007 | 491.426                         | 65.318   |
| 100.707  | 518.389                    | 88.944   | 493.353                         | 24.349   |
| 402.621  | 1425.530                   | 823.639  | 514.901                         | 47.089   |
| 733.871  | 2097.963                   | 1775.199 | 491.219                         | 101.274  |
| 87.493   | 294.181                    | 55.793   | 537.999                         | 23.945   |
| 73.008   | 744.932                    | 101.106  | 470.887                         | 25.189   |
| 1916.165 | 2652.870                   | 2210.725 | 442.861                         | 110.598  |
| 69.645   | 687.846                    | 98.106   | 465.824                         | 20.551   |
| 450.204  | 1404.160                   | 646.860  | 468.862                         | 30.898   |
| 257.700  | 1269.216                   | 535.211  | 508.853                         | 33.964   |
| 67.291   | 298.548                    | 39.388   | 520.308                         | 13.476   |
| 616.504  | 1041.468                   | 365.921  | 509.792                         | 53.515   |
|          |                            |          |                                 |          |
| 796.640  | 4960.341                   | 138.793  | 173.354                         | 166.386  |
| 310.048  | 4970.679                   | 90.049   | 448.415                         | 192.587  |
| 233.054  | 4960.341                   | 126.724  | 290.458                         | 190.335  |
| 227.148  | 4984.340                   | 101.356  | 16.214                          | 149.925  |
| 237.366  | 4970.679                   | 108.058  | 1213.151                        | 266.439  |
| 488.914  | 4980.938                   | 256.811  | 1787.042                        | 681.328  |
| 296.499  | 4648.179                   | 443.019  | 58.375                          | 22.183   |
| 250.174  | 4970.679                   | 132.071  | 52.099                          | 109.274  |
| 794.837  | 4958.610                   | 150.993  | 1428.435                        | 383.614  |
| 172.775  | 4982.640                   | 125.312  | 29.716                          | 175.671  |
| 257.502  | 4994.495                   | 100.839  | 1349.044                        | 325.782  |
| 214.856  | 4956.877                   | 102.765  | 294.640                         | 152.131  |
| 315.219  | 4955.142                   | 72.603   | 3025.584                        | 362.410  |
| 201.440  | 4965.520                   | 84.263   | 298.413                         | 150.266  |
| 193.469  | 4977.527                   | 65.809   | #VALUE!                         | #VALUE!  |
| 328.378  | 4958.610                   | 90.596   | 305.523                         | 352.334  |
| 418.073  | 4977.527                   | 89.739   | 377.927                         | 205.139  |
| 277.274  | 4982.640                   | 113.377  | 163.983                         | 232.276  |
| 263.842  | 4951.665                   | 127.277  | 1120.597                        | 257.702  |
| 311.734  | 4949.923                   | 145.586  | 1614.651                        | 311.359  |
| 300.088  | 4967.242                   | 84.191   | 1236.386                        | 215.693  |
| 231.042  | 4989.427                   | 130.831  | 1385.310                        | 380.925  |
| 550.625  | 4958.610                   | 72.477   | 0.000                           | 575.783  |
| 231.042  | 4974.107                   | 95.886   | 2019.055                        | 319.781  |
| 549.431  | 4992.807                   | 118.735  | 555.995                         | 346.578  |
| 308.757  | 4956.877                   | 132.989  | 1142.588                        | 284.318  |
| 452.969  | 4948.178                   | 163.927  | 1142.035                        | 318.379  |
| 190.043  | 4970.679                   | 114.061  | 453.505                         | 231.514  |
| 298.347  | 4974.107                   | 149.823  | 302.436                         | 281.536  |
| 415.995  | 4953.404                   | 181.665  | 133.295                         | 155.659  |
| 381.511  | 4987.733                   | 136.895  | 1034.133                        | 381.328  |
| 396.971  | 4956.877                   | 151.124  | 1353.427                        | 577.371  |

|         |          |         |           |          |
|---------|----------|---------|-----------|----------|
| 378.495 | 4979.233 | 119.549 | 2833.533  | 480.231  |
| 293.248 | 4972.394 | 149.952 | 509.851   | 308.671  |
| 462.965 | 4997.862 | 118.433 | -130.682  | 279.598  |
| 257.459 | 4996.180 | 94.827  | -197.347  | 489.098  |
| 292.972 | 4975.818 | 131.730 | 0.000     | 440.307  |
| 229.949 | 4951.665 | 151.520 | 1649.011  | 323.759  |
| 306.959 | 4927.067 | 153.396 | 284.903   | 144.066  |
| 326.717 | 4486.026 | 432.662 | 240.881   | 58.641   |
| 752.720 | 4876.472 | 295.734 | 215.986   | 140.621  |
| 399.612 | 4856.061 | 298.737 | 144.690   | 85.455   |
| 222.320 | 4645.995 | 225.260 | 213.151   | 38.401   |
| 159.936 | 4927.067 | 141.124 | 410.642   | 162.251  |
| 425.092 | 4963.796 | 108.432 | 154.381   | 136.028  |
| 498.471 | 4930.609 | 104.125 | 1277.305  | 225.483  |
| 208.541 | 4982.640 | 89.509  | 22.592    | 124.609  |
| 214.370 | 4984.340 | 184.826 | 11.632    | 241.326  |
| 436.414 | 4994.495 | 148.293 | #VALUE!   | #VALUE!  |
| 252.646 | 4977.527 | 107.687 | 89.122    | 485.991  |
|         |          |         |           |          |
| 299.000 | 4930.609 | 134.750 | 95.542    | 61.001   |
| 460.687 | 5004.405 | 53.709  | 6.502     | 231.721  |
| 388.551 | 4881.985 | 156.876 | 192.831   | 73.859   |
| 396.089 | 4898.390 | 180.500 | 98.343    | 54.494   |
| 288.941 | 4918.171 | 234.199 | 183.128   | 142.392  |
| 250.987 | 4951.665 | 163.641 | 176.617   | 161.963  |
| 275.678 | 4921.737 | 153.804 | 294.494   | 139.534  |
| 238.429 | 4941.178 | 146.225 | 508.316   | 211.543  |
| 432.216 | 4925.292 | 147.390 | 418.053   | 170.942  |
| 176.505 | 4990.104 | 50.531  | 85.941    | 151.551  |
| 364.008 | 4998.535 | 45.581  | 1089.098  | 210.791  |
| 376.084 | 4984.340 | 113.280 | 29.707    | 181.428  |
| 304.859 | 4987.733 | 89.279  | 231.221   | 227.895  |
| 287.136 | 4972.394 | 113.963 | 221.634   | 197.581  |
| 209.523 | 4937.664 | 103.758 | 604.962   | 163.090  |
| 250.814 | 4977.527 | 143.583 | 136.361   | 237.469  |
| 306.146 | 4992.807 | 124.672 | 60.937    | 305.385  |
| 307.869 | 4970.679 | 138.074 | 191.508   | 214.264  |
| 181.082 | 4951.665 | 133.337 | 166.951   | 130.314  |
| 269.097 | 5007.915 | 106.050 | -292.111  | 210.425  |
| 331.051 | 4935.904 | 134.393 | 553.192   | 194.834  |
| 287.931 | 4986.038 | 107.227 | 63.931    | 211.814  |
| 197.483 | 4975.818 | 113.767 | 1222.400  | 288.797  |
| 638.433 | 4962.070 | 120.585 | 55.597    | 74.346   |
| 186.404 | 4989.427 | 172.459 | -12.717   | 301.791  |
| 199.009 | 4982.640 | 107.410 | 108.172   | 204.905  |
| 378.480 | 4986.038 | 119.141 | 318.962   | 289.842  |
| 635.157 | 5002.898 | 94.506  | -364.081  | 592.728  |
| 548.231 | 5018.556 | 49.225  | -5689.769 | 1570.951 |
| 538.230 | 4980.938 | 167.226 | 69.460    | 256.182  |
| 529.328 | 5001.222 | 112.321 | -185.542  | 212.711  |

|          |          |         |           |          |
|----------|----------|---------|-----------|----------|
| 259.508  | 4987.733 | 142.847 | 94.260    | 302.335  |
| 1172.992 | 5037.628 | 150.897 | -1044.046 | 443.883  |
| 271.196  | 5002.898 | 94.506  | 1184.548  | 347.330  |
| 368.524  | 5006.245 | 70.760  | -330.343  | 185.316  |
| 225.313  | 5007.915 | 76.592  | -379.474  | 200.948  |
| 1041.727 | 4992.807 | 100.925 | -53.996   | 205.832  |
| 284.796  | 4994.495 | 83.044  | -57.780   | 200.528  |
| 356.192  | 5011.250 | 105.871 | -284.534  | 187.699  |
| 410.547  | 5004.573 | 47.803  | -307.365  | 156.854  |
| 454.997  | 4995.843 | 52.756  | -7802.717 | 2332.840 |
| 692.072  | 5009.583 | 88.301  | #NUM!     | #VALUE!  |
| 230.315  | 4999.543 | 159.749 | -155.763  | 277.938  |
| 456.167  | 5002.898 | 94.506  | 1362.315  | 356.185  |
| 612.748  | 4962.070 | 96.468  | 250.041   | 150.150  |
| 170.756  | 4968.962 | 162.227 | 84.012    | 163.119  |
| 234.588  | 4992.807 | 136.545 | -64.932   | 230.631  |
| 445.279  | 4963.796 | 120.480 | 262.991   | 483.616  |
| 631.357  | 4974.107 | 125.851 | 94.115    | 166.802  |
| 235.417  | 4984.340 | 125.205 | 205.445   | 273.680  |
| 208.541  | 4946.432 | 127.611 | 315.205   | 162.390  |
| 368.000  | 4953.404 | 145.332 | 167.972   | 146.441  |
| 411.446  | 4997.862 | 100.668 | 0.000     | 481.163  |
| 416.023  | 4986.038 | 77.441  | -3155.743 | 1795.990 |
| 422.511  | 5042.516 | 81.051  | -2481.884 | 1398.378 |
| 308.621  | 5004.573 | 88.524  | -377.805  | 538.007  |
| 467.054  | 5004.573 | 94.426  | #VALUE!   | #VALUE!  |
| 380.788  | 4982.640 | 107.410 | 571.313   | 272.291  |
| 279.245  | 4999.543 | 136.082 | -78.477   | 377.323  |
|          |          |         |           |          |
| 916.269  | 4980.938 | 149.309 | 12.180    | 122.352  |
| 772.653  | 4946.432 | 115.457 | 53.430    | 45.422   |
| 1286.787 | 4928.839 | 140.999 | 711.352   | 271.171  |
| 344.565  | 4942.932 | 133.922 | 247.811   | 143.251  |
| 873.401  | 4912.805 | 302.802 | #VALUE!   | #VALUE!  |
| 274.172  | 4443.524 | 232.240 | 214.528   | 30.925   |
| 195.031  | 4726.607 | 440.157 | 66.482    | 31.049   |
| 211.362  | 4903.814 | 372.442 | 60.980    | 74.376   |
| 505.921  | 4932.376 | 232.544 | 20.920    | 26.607   |
| 195.753  | 4061.872 | 320.915 | 128.055   | 14.942   |
| 201.619  | 4453.645 | 261.979 | 177.261   | 27.569   |
| 240.739  | 4846.679 | 434.222 | 152.282   | 145.128  |
| 339.327  | 4703.764 | 232.792 | 201.899   | 47.403   |
| 380.411  | 4880.150 | 238.669 | 75.969    | 48.216   |
| 1635.768 | 4909.216 | 222.865 | 450.846   | 264.043  |
| 280.088  | 4810.418 | 312.027 | 75.528    | 37.426   |
| 275.251  | 5016.235 | 492.823 | -15.672   | 65.017   |
| 455.972  | 4956.877 | 544.048 | 70.717    | 314.665  |
| 114.870  | 4578.760 | 174.429 | 114.759   | 14.409   |
| 117.821  | 4583.348 | 391.615 | 71.561    | 18.737   |
| 234.278  | 4946.432 | 528.673 | 13.827    | 53.666   |

|          |          |         |           |         |
|----------|----------|---------|-----------|---------|
| 221.123  | 4703.764 | 376.575 | 133.839   | 47.731  |
| 111.375  | 4790.932 | 137.821 | 82.315    | 16.705  |
| 151.752  | 4816.209 | 200.945 | 99.169    | 32.200  |
| 204.647  | 4806.544 | 149.797 | 128.112   | 29.912  |
| 346.404  | 4925.292 | 141.249 | 119.771   | 70.884  |
| 116.381  | 4785.031 | 164.547 | 162.759   | 35.508  |
| 163.682  | 4701.668 | 191.905 | 193.780   | 35.145  |
| 156.435  | 4718.345 | 394.329 | 62.974    | 25.667  |
| 1074.274 | 4992.807 | 106.862 | -60.601   | 156.173 |
| 157.766  | 4630.604 | 375.838 | 60.263    | 18.031  |
| 148.568  | 4771.159 | 251.811 | 92.966    | 29.878  |
| 357.281  | 4876.472 | 308.319 | 115.518   | 84.267  |
| 371.029  | 4903.814 | 192.428 | 46.954    | 31.521  |
| 492.544  | 4632.813 | 269.185 | 126.464   | 34.150  |
| 159.338  | 4527.234 | 394.644 | 158.215   | 36.017  |
| 245.308  | 4703.764 | 273.873 | 150.840   | 40.746  |
| 383.747  | 5040.889 | 202.794 | -170.967  | 139.963 |
| 127.363  | 4724.546 | 264.358 | 72.288    | 20.204  |
| 756.290  | 5022.854 | 81.863  | -2386.617 | 675.423 |
| 438.726  | 4948.178 | 115.356 | 99.417    | 75.963  |
| 394.234  | 4965.520 | 156.489 | 90.243    | 146.224 |
| 391.511  | 4975.818 | 131.730 | 21.055    | 81.868  |
| 180.280  | 4669.830 | 501.085 | 106.850   | 46.083  |
| 136.208  | 4841.019 | 294.559 | 53.943    | 30.307  |
| 157.554  | 4831.531 | 250.905 | 58.268    | 26.375  |
| 282.254  | 4974.107 | 83.901  | 77.135    | 110.125 |
| 115.865  | 4730.719 | 141.922 | 264.918   | 39.298  |
| 185.660  | 4635.019 | 318.436 | 210.793   | 50.081  |
| 305.638  | 4935.904 | 109.958 | 244.266   | 109.290 |
| 171.202  | 4765.170 | 312.361 | 215.893   | 80.750  |
| 342.103  | 4517.650 | 149.591 | 264.956   | 36.371  |
| 147.198  | 4601.546 | 287.597 | 178.259   | 35.503  |
| 84.304   | 4478.622 | 76.167  | 241.593   | 13.545  |
| 254.063  | 4632.813 | 212.514 | 76.735    | 15.731  |
| 135.027  | 4747.041 | 214.556 | 118.729   | 29.155  |
| 112.630  | 4433.327 | 147.778 | 262.229   | 20.956  |
| 327.804  | 4955.142 | 163.356 | 99.869    | 121.045 |
| 454.160  | 4999.543 | 124.249 | -145.643  | 209.060 |
| 435.457  | 4842.908 | 428.633 | 176.853   | 132.439 |
| 149.093  | 4863.519 | 449.622 | 38.718    | 39.474  |
| 142.801  | 4712.115 | 211.397 | 112.256   | 23.954  |
| 133.096  | 4848.561 | 510.375 | 27.571    | 28.767  |
| 226.222  | 4857.929 | 247.659 | 97.968    | 50.963  |
| 1122.010 | 4693.251 | 653.752 | 28.318    | 17.458  |
| 155.963  | 4730.719 | 743.399 | 40.062    | 32.062  |
| 120.783  | 4783.058 | 283.294 | 66.829    | 25.700  |
| 206.730  | 4850.440 | 376.052 | 31.782    | 29.122  |
| 214.759  | 4956.877 | 181.349 | 31.240    | 55.053  |
| 264.534  | 4996.180 | 88.900  | 0.000     | 450.088 |
| 168.279  | 4104.897 | 162.035 | 225.241   | 18.392  |

|         |          |         |         |        |
|---------|----------|---------|---------|--------|
| 199.673 | 4578.760 | 210.768 | 212.892 | 30.889 |
| 163.283 | 4488.485 | 136.474 | 237.812 | 21.239 |
| 122.750 | 4435.883 | 147.604 | 271.344 | 22.537 |
| 205.225 | 4610.554 | 93.070  | 162.493 | 17.230 |
| 216.052 | 4632.813 | 361.274 | 177.273 | 47.571 |
| 161.356 | 4619.502 | 463.376 | 111.097 | 37.748 |
| 118.479 | 4389.109 | 396.845 | 127.704 | 22.683 |
| 183.197 | 4857.929 | 203.208 | 154.166 | 62.917 |
| 187.683 | 4821.975 | 297.334 | 113.363 | 54.581 |





| Sample   | $^{207}\text{Pb}/^{235}\text{U}$ | Error $2\sigma$ | $^{206}\text{Pb}/^{238}\text{U}$ | Error $2\sigma$ | rrelation_6_38 | $^{238}\text{U}/^{206}\text{Pb}$ |
|----------|----------------------------------|-----------------|----------------------------------|-----------------|----------------|----------------------------------|
| PCA_1    | 5.420                            | 0.290           | 0.349                            | 0.014           | 0.462          | 2.865                            |
| PCA_2    | 5.910                            | 0.270           | 0.351                            | 0.012           | 0.349          | 2.849                            |
| PCA_3    | 5.570                            | 0.300           | 0.336                            | 0.014           | 0.390          | 2.976                            |
| PCA_4    | 5.570                            | 0.290           | 0.351                            | 0.012           | 0.424          | 2.849                            |
| PCA_5    | 5.980                            | 0.280           | 0.356                            | 0.016           | 0.451          | 2.809                            |
| PCA_6    | 6.170                            | 0.370           | 0.362                            | 0.011           | 0.372          | 2.762                            |
| PCA_7    | 5.690                            | 0.320           | 0.335                            | 0.011           | 0.365          | 2.985                            |
| PCA_8    | 5.470                            | 0.300           | 0.356                            | 0.012           | 0.233          | 2.809                            |
| PCA_9    | 6.050                            | 0.310           | 0.361                            | 0.014           | 0.493          | 2.770                            |
| PCA_10   | 5.480                            | 0.290           | 0.344                            | 0.012           | 0.516          | 2.907                            |
| PCA_11   | 5.520                            | 0.290           | 0.362                            | 0.014           | 0.390          | 2.762                            |
| PCA_12   | 7.900                            | 0.680           | 0.372                            | 0.014           | 0.566          | 2.688                            |
| PCA_13   | 5.340                            | 0.290           | 0.356                            | 0.014           | 0.431          | 2.809                            |
| PCA_14   | 5.070                            | 0.310           | 0.306                            | 0.010           | 0.381          | 3.268                            |
| PCA_15   | 4.950                            | 0.310           | 0.305                            | 0.011           | 0.313          | 3.279                            |
| PCA_16   | 5.470                            | 0.240           | 0.344                            | 0.010           | 0.253          | 2.905                            |
| PCA_17   | 5.420                            | 0.310           | 0.349                            | 0.012           | 0.391          | 2.865                            |
| PCA_18   | 5.720                            | 0.310           | 0.357                            | 0.014           | 0.344          | 2.801                            |
| PCA_19   | 5.690                            | 0.280           | 0.355                            | 0.011           | 0.271          | 2.817                            |
| PCA_20   | 5.320                            | 0.280           | 0.329                            | 0.011           | 0.211          | 3.040                            |
| PCA_21   | 5.200                            | 0.310           | 0.342                            | 0.013           | 0.505          | 2.924                            |
| PCA_22   | 5.320                            | 0.270           | 0.345                            | 0.011           | 0.186          | 2.899                            |
| PCA_23   | 5.470                            | 0.260           | 0.345                            | 0.012           | 0.375          | 2.899                            |
| PCA_24   | 5.670                            | 0.340           | 0.365                            | 0.014           | 0.565          | 2.740                            |
| PCA_25   | 5.590                            | 0.260           | 0.342                            | 0.010           | 0.340          | 2.924                            |
| PCA_26   | 6.480                            | 0.440           | 0.363                            | 0.016           | 0.705          | 2.755                            |
| PCA_27   | 5.620                            | 0.260           | 0.368                            | 0.013           | 0.309          | 2.717                            |
| PCA_28   | 5.700                            | 0.300           | 0.356                            | 0.015           | 0.489          | 2.809                            |
| PCA_29   | 5.210                            | 0.240           | 0.332                            | 0.012           | 0.478          | 3.012                            |
|          |                                  |                 |                                  |                 |                |                                  |
| R_R19_1  | 0.620                            | 0.110           | 0.076                            | 0.004           | 0.290          | 13.141                           |
| R_R19_2  | 0.720                            | 0.110           | 0.084                            | 0.005           | 0.010          | 11.933                           |
| R_R19_3  | 0.561                            | 0.094           | 0.078                            | 0.005           | 0.221          | 12.837                           |
| R_R19_4  | 0.645                            | 0.098           | 0.082                            | 0.005           | 0.188          | 12.255                           |
| R_R19_5  | 0.710                            | 0.100           | 0.082                            | 0.004           | 0.164          | 12.136                           |
| R_R19_6  | 0.760                            | 0.110           | 0.084                            | 0.004           | 0.290          | 11.848                           |
| R_R19_7  | 0.723                            | 0.093           | 0.081                            | 0.005           | 0.076          | 12.285                           |
| R_R19_8  | 0.620                            | 0.100           | 0.082                            | 0.005           | 0.010          | 12.136                           |
| R_R19_9  | 0.557                            | 0.076           | 0.080                            | 0.005           | 0.010          | 12.563                           |
| R_R19_10 | 0.715                            | 0.088           | 0.086                            | 0.005           | 0.261          | 11.682                           |
| R_R19_11 | 0.608                            | 0.098           | 0.077                            | 0.005           | 0.122          | 13.004                           |
| R_R19_12 | 0.595                            | 0.091           | 0.073                            | 0.003           | 0.363          | 13.717                           |
| R_R19_13 | 0.670                            | 0.110           | 0.081                            | 0.005           | 0.027          | 12.346                           |
| R_R19_14 | 0.670                            | 0.096           | 0.083                            | 0.004           | 0.218          | 11.990                           |
| R_R19_15 | 0.631                            | 0.078           | 0.079                            | 0.005           | 0.125          | 12.594                           |
| R_R19_16 | 0.761                            | 0.096           | 0.080                            | 0.005           | 0.143          | 12.453                           |
| R_R19_17 | 0.474                            | 0.079           | 0.075                            | 0.004           | 0.188          | 13.263                           |
| R_R19_18 | 0.557                            | 0.076           | 0.077                            | 0.004           | 0.091          | 12.953                           |
| R_R19_19 | 0.690                            | 0.110           | 0.091                            | 0.004           | 0.265          | 10.989                           |

|          |        |       |       |       |       |        |
|----------|--------|-------|-------|-------|-------|--------|
| R_R19_20 | 0.650  | 0.110 | 0.079 | 0.004 | 0.117 | 12.723 |
| R_R19_21 | 0.643  | 0.092 | 0.079 | 0.004 | 0.105 | 12.626 |
| R_R19_22 | 0.569  | 0.076 | 0.070 | 0.004 | 0.212 | 14.306 |
| R_R19_23 | 0.546  | 0.090 | 0.076 | 0.004 | 0.222 | 13.123 |
| R_R19_24 | 0.682  | 0.084 | 0.083 | 0.004 | 0.216 | 12.077 |
| R_R19_25 | 0.578  | 0.083 | 0.084 | 0.005 | 0.270 | 11.933 |
| R_R19_26 | 0.493  | 0.080 | 0.062 | 0.004 | 0.198 | 16.181 |
| R_R19_27 | 0.462  | 0.075 | 0.070 | 0.005 | 0.145 | 14.306 |
| R_R19_28 | 0.590  | 0.100 | 0.076 | 0.005 | 0.430 | 13.245 |
| R_R19_29 | 0.462  | 0.074 | 0.073 | 0.005 | 0.158 | 13.624 |
| R632_1   | 0.645  | 0.022 | 0.081 | 0.002 | 0.345 | 12.407 |
| R632_2   | 0.653  | 0.022 | 0.083 | 0.001 | 0.384 | 12.077 |
| R632_3   | 0.658  | 0.022 | 0.080 | 0.001 | 0.270 | 12.563 |
| R632_4   | 0.634  | 0.023 | 0.081 | 0.002 | 0.614 | 12.346 |
| R632_5   | 0.620  | 0.019 | 0.079 | 0.001 | 0.416 | 12.594 |
| R632_6   | 0.671  | 0.016 | 0.084 | 0.002 | 0.353 | 11.862 |
| R632_7   | 0.636  | 0.019 | 0.080 | 0.002 | 0.489 | 12.531 |
| R632_8   | 0.631  | 0.023 | 0.081 | 0.002 | 0.398 | 12.285 |
| R632_9   | 0.669  | 0.027 | 0.083 | 0.002 | 0.381 | 11.990 |
| R632_10  | 0.646  | 0.029 | 0.080 | 0.002 | 0.499 | 12.500 |
| R632_11  | 0.611  | 0.021 | 0.077 | 0.002 | 0.209 | 12.970 |
| R632_12  | 0.631  | 0.022 | 0.080 | 0.002 | 0.484 | 12.547 |
| R632_13  | 0.670  | 0.020 | 0.085 | 0.002 | 0.306 | 11.751 |
| R632_14  | 0.668  | 0.020 | 0.083 | 0.002 | 0.545 | 12.063 |
| R632_15  | 0.596  | 0.018 | 0.076 | 0.002 | 0.140 | 13.141 |
| R632_16  | 0.678  | 0.023 | 0.084 | 0.002 | 0.270 | 11.905 |
| R632_17  | 0.628  | 0.022 | 0.083 | 0.002 | 0.442 | 12.092 |
| R632_18  | 0.658  | 0.024 | 0.082 | 0.002 | 0.354 | 12.195 |
| R632_19  | 0.639  | 0.023 | 0.082 | 0.002 | 0.558 | 12.255 |
| R632_20  | 0.632  | 0.023 | 0.080 | 0.002 | 0.385 | 12.484 |
| R632_21  | 0.638  | 0.023 | 0.080 | 0.002 | 0.202 | 12.531 |
| R632_22  | 0.653  | 0.022 | 0.083 | 0.002 | 0.215 | 11.990 |
| R632_23  | 0.573  | 0.022 | 0.072 | 0.002 | 0.531 | 13.850 |
| R632_24  | 0.700  | 0.019 | 0.089 | 0.002 | 0.624 | 11.249 |
| R632_25  | 0.630  | 0.018 | 0.078 | 0.002 | 0.329 | 12.870 |
| R632_26  | 0.578  | 0.020 | 0.070 | 0.002 | 0.475 | 14.265 |
| R632_27  | 0.575  | 0.022 | 0.074 | 0.002 | 0.614 | 13.605 |
| R632_28  | 0.680  | 0.020 | 0.083 | 0.002 | 0.552 | 12.019 |
| R632_29  | 0.685  | 0.019 | 0.086 | 0.002 | 0.365 | 11.641 |
| X11B_1   | 55.100 | 3.000 | 0.476 | 0.025 | 0.758 | 2.101  |
| X11B_2   | 84.100 | 6.400 | 0.725 | 0.064 | 0.954 | 1.379  |
| X11B_3   | 15.600 | 2.700 | 0.153 | 0.026 | 0.870 | 6.536  |
| X11B_4   | 19.700 | 2.700 | 0.188 | 0.022 | 0.937 | 5.319  |
| X11B_5   | 18.580 | 0.990 | 0.189 | 0.009 | 0.752 | 5.291  |
| X11B_6   | 20.780 | 0.790 | 0.215 | 0.008 | 0.472 | 4.647  |
| X11B_7   | 5.270  | 0.560 | 0.057 | 0.005 | 0.764 | 17.422 |
| X11B_8   | 18.100 | 1.200 | 0.165 | 0.010 | 0.686 | 6.075  |
| X11B_9   | 13.200 | 1.300 | 0.124 | 0.012 | 0.866 | 8.065  |

|         |          |         |        |       |       |       |
|---------|----------|---------|--------|-------|-------|-------|
| X11B_10 | 41.400   | 1.700   | 0.368  | 0.016 | 0.881 | 2.717 |
| X11B_11 | 49.800   | 3.700   | 0.452  | 0.031 | 0.885 | 2.212 |
| X11B_12 | 11.750   | 0.600   | 0.145  | 0.007 | 0.870 | 6.916 |
| X11B_13 | 13.840   | 0.440   | 0.164  | 0.005 | 0.454 | 6.098 |
| X11B_14 | 30.650   | 0.900   | 0.277  | 0.008 | 0.571 | 3.613 |
| X11B_15 | 52.100   | 1.900   | 0.463  | 0.023 | 0.827 | 2.160 |
| X11B_16 | 22.300   | 1.700   | 0.217  | 0.016 | 0.828 | 4.608 |
|         |          |         |        |       |       |       |
| X93_1   | 108.600  | 7.500   | 0.910  | 0.058 | 0.966 | 1.099 |
| X93_2   | 138.800  | 6.800   | 1.204  | 0.065 | 0.912 | 0.831 |
| X93_3   | 273.000  | 10.000  | 2.381  | 0.092 | 0.882 | 0.420 |
| X93_4   | 360.000  | 18.000  | 3.060  | 0.140 | 0.907 | 0.327 |
| X93_5   | 790.000  | 130.000 | 6.900  | 1.100 | 0.980 | 0.145 |
| X93_6   | 1620.000 | 470.000 | 13.900 | 4.000 | 0.995 | 0.072 |
| X93_7   | 272.000  | 26.000  | 2.310  | 0.210 | 0.911 | 0.433 |
| X93_8   | 1200.000 | 340.000 | 10.900 | 3.300 | 0.911 | 0.092 |
| X93_9   | 650.000  | 120.000 | 5.500  | 1.000 | 0.985 | 0.182 |
| X93_10  | 1170.000 | 200.000 | 10.000 | 1.700 | 0.986 | 0.100 |
| X93_11  | 245.000  | 24.000  | 2.270  | 0.220 | 0.952 | 0.441 |
| X93_12  | 312.000  | 23.000  | 2.700  | 0.190 | 0.915 | 0.370 |
| X93_13  | 236.000  | 17.000  | 2.070  | 0.160 | 0.927 | 0.483 |
| X93_14  | 255.000  | 18.000  | 2.200  | 0.150 | 0.914 | 0.455 |
| X93_15  | 214.000  | 18.000  | 1.840  | 0.150 | 0.936 | 0.543 |
| X93_16  | 287.000  | 17.000  | 2.560  | 0.170 | 0.913 | 0.391 |
| X93_17  | 82.000   | 13.000  | 0.760  | 0.120 | 0.961 | 1.316 |
| X93_18  | 800.000  | 210.000 | 7.000  | 1.800 | 0.991 | 0.143 |
| X93_19  | 437.000  | 40.000  | 3.840  | 0.350 | 0.934 | 0.260 |
| X93_20  | 440.000  | 65.000  | 4.040  | 0.650 | 0.950 | 0.248 |
| X93_21  | 226.000  | 20.000  | 1.910  | 0.170 | 0.962 | 0.524 |
| X93_22  | 560.000  | 87.000  | 4.660  | 0.680 | 0.979 | 0.215 |
| X93_23  | 1410.000 | 380.000 | 12.500 | 3.400 | 0.993 | 0.080 |
| X93_24  | 192.000  | 15.000  | 1.700  | 0.140 | 0.872 | 0.588 |
| X93_25  | 225.000  | 15.000  | 1.870  | 0.130 | 0.856 | 0.535 |
| X93_26  | 920.000  | 110.000 | 7.900  | 1.000 | 0.981 | 0.127 |
| X93_27  | 316.000  | 32.000  | 2.690  | 0.290 | 0.934 | 0.372 |
| X93_28  | 78.400   | 5.600   | 0.686  | 0.040 | 0.479 | 1.458 |
| X93_29  | 238.000  | 28.000  | 2.120  | 0.270 | 0.950 | 0.472 |
| X93_30  | 69.400   | 6.500   | 0.623  | 0.050 | 0.876 | 1.605 |
| X93_31  | 74.100   | 8.300   | 0.656  | 0.071 | 0.934 | 1.524 |
| X93_32  | 173.000  | 15.000  | 1.550  | 0.140 | 0.961 | 0.645 |
| X93_33  | 89.000   | 16.000  | 0.790  | 0.140 | 0.947 | 1.266 |
| X93_34  | 148.000  | 15.000  | 1.300  | 0.120 | 0.952 | 0.769 |
| X93_35  | 131.000  | 11.000  | 1.160  | 0.110 | 0.953 | 0.862 |
| X93_36  | 384.000  | 28.000  | 3.330  | 0.280 | 0.878 | 0.300 |
| X93_37  | 532.000  | 39.000  | 4.710  | 0.360 | 0.900 | 0.212 |
| X93_38  | 970.000  | 130.000 | 8.200  | 1.100 | 0.974 | 0.122 |
| X93_39  | 3230.000 | 630.000 | 28.200 | 5.300 | 0.989 | 0.035 |
| X93_40  | 970.000  | 190.000 | 8.500  | 1.700 | 0.989 | 0.118 |
| X93_41  | 183.000  | 14.000  | 1.650  | 0.130 | 0.807 | 0.606 |
| X93_42  | 156.000  | 16.000  | 1.370  | 0.120 | 0.879 | 0.730 |

|        |          |         |        |       |       |        |
|--------|----------|---------|--------|-------|-------|--------|
| X93_43 | 55.700   | 5.400   | 0.488  | 0.040 | 0.841 | 2.049  |
| X93_44 | 279.000  | 31.000  | 2.410  | 0.300 | 0.927 | 0.415  |
| X93_45 | 2710.000 | 410.000 | 22.700 | 3.300 | 0.993 | 0.044  |
| X93_46 | 399.000  | 39.000  | 3.430  | 0.340 | 0.920 | 0.292  |
| X93_47 | 161.000  | 18.000  | 1.360  | 0.150 | 0.876 | 0.735  |
| X93_48 | 151.000  | 44.000  | 1.200  | 0.240 | 0.978 | 0.833  |
| X93_49 | 111.200  | 7.900   | 0.979  | 0.064 | 0.885 | 1.021  |
| X93_50 | 273.000  | 23.000  | 2.290  | 0.170 | 0.850 | 0.437  |
| X93_51 | 2500.000 | 780.000 | 19.300 | 5.700 | 0.989 | 0.052  |
| X93_52 | 262.000  | 56.000  | 2.160  | 0.470 | 0.981 | 0.463  |
| X93_53 | 212.000  | 22.000  | 1.910  | 0.200 | 0.902 | 0.524  |
| X93_54 | 1620.000 | 220.000 | 14.200 | 1.900 | 0.991 | 0.070  |
| X93_55 | 130.000  | 11.000  | 1.104  | 0.088 | 0.890 | 0.906  |
| X93_56 | 320.000  | 32.000  | 2.710  | 0.280 | 0.890 | 0.369  |
| X93_57 | 66.700   | 5.300   | 0.600  | 0.045 | 0.851 | 1.667  |
|        |          |         |        |       |       |        |
| X96_1  | 590.000  | 120.000 | 5.100  | 1.100 | 0.989 | 0.196  |
| X96_2  | 316.000  | 35.000  | 2.620  | 0.280 | 0.985 | 0.382  |
| X96_3  | 415.000  | 23.000  | 3.610  | 0.220 | 0.955 | 0.277  |
| X96_4  | 165.000  | 6.800   | 1.407  | 0.061 | 0.889 | 0.711  |
| X96_5  | 2380.000 | 280.000 | 21.200 | 2.700 | 0.984 | 0.047  |
| X96_6  | 304.000  | 31.000  | 2.570  | 0.260 | 0.985 | 0.389  |
| X96_7  | 323.000  | 18.000  | 2.780  | 0.160 | 0.936 | 0.360  |
| X96_8  | 1278.000 | 72.000  | 10.770 | 0.600 | 0.973 | 0.093  |
| X96_9  | 136.000  | 13.000  | 1.150  | 0.100 | 0.946 | 0.870  |
| X96_10 | 5.240    | 0.360   | 0.050  | 0.003 | 0.955 | 19.881 |
| X96_11 | 197.000  | 13.000  | 1.670  | 0.110 | 0.939 | 0.599  |
| X96_12 | 262.000  | 35.000  | 2.320  | 0.320 | 0.982 | 0.431  |
| X96_13 | 45.700   | 4.900   | 0.412  | 0.047 | 0.917 | 2.427  |
| X96_14 | 157.900  | 8.500   | 1.356  | 0.078 | 0.925 | 0.737  |
| X96_15 | 1405.000 | 77.000  | 12.050 | 0.740 | 0.926 | 0.083  |
| X96_16 | 314.000  | 20.000  | 2.690  | 0.180 | 0.961 | 0.372  |
| X96_17 | 147.000  | 5.700   | 1.299  | 0.053 | 0.918 | 0.770  |
| X96_18 | 602.000  | 24.000  | 5.140  | 0.190 | 0.952 | 0.195  |
| X96_19 | 5750.000 | 740.000 | 50.200 | 6.400 | 0.991 | 0.020  |
| X96_20 | 439.000  | 38.000  | 3.790  | 0.320 | 0.965 | 0.264  |
| X96_21 | 234.000  | 40.000  | 2.030  | 0.330 | 0.985 | 0.493  |
| X96_22 | 1470.000 | 320.000 | 12.400 | 2.700 | 0.995 | 0.081  |
| X96_23 | 461.000  | 33.000  | 3.960  | 0.280 | 0.975 | 0.253  |
| X96_24 | 299.000  | 17.000  | 2.660  | 0.150 | 0.943 | 0.376  |
| X96_25 | 185.000  | 43.000  | 1.620  | 0.390 | 0.991 | 0.617  |
| X96_26 | 107.500  | 9.500   | 0.962  | 0.092 | 0.940 | 1.040  |
| X96_27 | 339.000  | 30.000  | 3.020  | 0.290 | 0.947 | 0.331  |
| X96_30 | 920.000  | 320.000 | 6.900  | 1.900 | 0.998 | 0.145  |
| X96_31 | 451.000  | 25.000  | 3.780  | 0.210 | 0.916 | 0.265  |
| X96_32 | 153.000  | 22.000  | 1.300  | 0.180 | 0.981 | 0.769  |
| X96_33 | 326.000  | 17.000  | 2.890  | 0.160 | 0.918 | 0.346  |
| X96_34 | 337.000  | 24.000  | 2.890  | 0.200 | 0.967 | 0.346  |
| X96_35 | 1520.000 | 130.000 | 13.000 | 1.100 | 0.978 | 0.077  |
| X96_36 | 1620.000 | 120.000 | 13.740 | 0.960 | 0.980 | 0.073  |

|        |          |          |        |        |       |        |
|--------|----------|----------|--------|--------|-------|--------|
| X96_37 | 700.000  | 46.000   | 6.020  | 0.390  | 0.977 | 0.166  |
| X96_38 | 1750.000 | 250.000  | 14.600 | 2.100  | 0.995 | 0.068  |
| X96_39 | 3060.000 | 450.000  | 26.100 | 3.700  | 0.984 | 0.038  |
| X96_40 | 81.800   | 6.700    | 0.682  | 0.060  | 0.763 | 1.466  |
| X96_41 | 32.300   | 3.100    | 0.301  | 0.035  | 0.888 | 3.322  |
| X96_42 | 3600.000 | 1400.000 | 30.000 | 12.000 | 0.999 | 0.033  |
| X96_43 | 565.000  | 30.000   | 4.900  | 0.270  | 0.926 | 0.204  |
| X96_44 | 495.000  | 42.000   | 4.040  | 0.340  | 0.929 | 0.248  |
| X96_45 | 630.000  | 59.000   | 5.450  | 0.510  | 0.979 | 0.183  |
| X96_46 | 222.000  | 31.000   | 1.950  | 0.260  | 0.990 | 0.513  |
| X96_47 | 108.000  | 18.000   | 0.980  | 0.170  | 0.994 | 1.020  |
| X96_48 | 505.000  | 52.000   | 4.360  | 0.450  | 0.985 | 0.229  |
| X96_49 | 2450.000 | 280.000  | 20.900 | 2.400  | 0.987 | 0.048  |
| X96_50 | 150.000  | 22.000   | 1.320  | 0.200  | 0.980 | 0.758  |
| X96_51 | 275.000  | 19.000   | 2.280  | 0.170  | 0.955 | 0.439  |
| X96_52 | 92.000   | 8.100    | 0.799  | 0.071  | 0.917 | 1.252  |
| X96_53 | 940.000  | 190.000  | 8.500  | 1.800  | 0.994 | 0.118  |
| X96_54 | 112.000  | 17.000   | 0.880  | 0.130  | 0.966 | 1.136  |
| X96_55 | 1510.000 | 110.000  | 12.610 | 0.900  | 0.962 | 0.079  |
| X96_56 | 200.000  | 11.000   | 1.725  | 0.091  | 0.964 | 0.580  |
| X96_57 | 172.400  | 5.800    | 1.482  | 0.053  | 0.854 | 0.675  |
| X96_58 | 1019.000 | 97.000   | 8.650  | 0.790  | 0.983 | 0.116  |
| X96_59 | 144.000  | 11.000   | 1.268  | 0.096  | 0.932 | 0.789  |
| X96_60 | 46.500   | 3.100    | 0.401  | 0.026  | 0.845 | 2.494  |
| X96_61 | 73.300   | 3.300    | 0.636  | 0.028  | 0.852 | 1.572  |
| X96_62 | 16.700   | 2.000    | 0.155  | 0.019  | 0.885 | 6.452  |
| X96_63 | 66.100   | 4.500    | 0.571  | 0.039  | 0.915 | 1.751  |
| X96_64 | 292.000  | 16.000   | 2.430  | 0.150  | 0.950 | 0.412  |
| X96_65 | 217.000  | 21.000   | 1.850  | 0.180  | 0.931 | 0.541  |
| X96_66 | 2220.000 | 310.000  | 18.900 | 2.600  | 0.993 | 0.053  |
| X96_67 | 86.000   | 6.600    | 0.759  | 0.056  | 0.907 | 1.318  |
| X96_68 | 124.000  | 26.000   | 1.070  | 0.210  | 0.996 | 0.935  |
| X96_69 | 247.000  | 22.000   | 2.150  | 0.180  | 0.827 | 0.465  |
| X96_70 | 730.000  | 120.000  | 6.300  | 1.100  | 0.964 | 0.159  |
| X96_71 | 154.000  | 12.000   | 1.350  | 0.110  | 0.960 | 0.741  |
| X96_72 | 63.100   | 3.500    | 0.565  | 0.028  | 0.764 | 1.770  |
| X96_73 | 862.000  | 79.000   | 7.260  | 0.640  | 0.974 | 0.138  |
| X96_74 | 318.000  | 42.000   | 2.750  | 0.340  | 0.979 | 0.364  |
| X96_75 | 1007.000 | 84.000   | 8.440  | 0.680  | 0.966 | 0.118  |
| X96_76 | 203.000  | 24.000   | 1.710  | 0.180  | 0.973 | 0.585  |
| X96_77 | 361.000  | 58.000   | 3.200  | 0.510  | 0.985 | 0.313  |
| X96_78 | 87.000   | 12.000   | 0.780  | 0.110  | 0.972 | 1.282  |
| X96_79 | 173.000  | 16.000   | 1.480  | 0.140  | 0.962 | 0.676  |
| X96_80 | 116.000  | 11.000   | 0.990  | 0.081  | 0.964 | 1.010  |
| X96_81 | 540.000  | 100.000  | 4.390  | 0.830  | 0.995 | 0.228  |
| X96_82 | 1062.000 | 80.000   | 9.320  | 0.700  | 0.970 | 0.107  |
| X96_83 | 64.000   | 11.000   | 0.554  | 0.095  | 0.991 | 1.805  |
| X96_84 | 7.400    | 1.300    | 0.070  | 0.013  | 0.990 | 14.286 |
| X96_85 | 95.600   | 4.600    | 0.836  | 0.037  | 0.856 | 1.196  |
| X96_86 | 480.000  | 51.000   | 4.220  | 0.440  | 0.937 | 0.237  |

|        |         |         |       |       |       |       |
|--------|---------|---------|-------|-------|-------|-------|
| X96_87 | 360.000 | 200.000 | 3.000 | 1.700 | 0.987 | 0.333 |
| X96_88 | 171.000 | 14.000  | 1.460 | 0.120 | 0.958 | 0.685 |
| X96_89 | 319.000 | 17.000  | 2.800 | 0.150 | 0.930 | 0.357 |
| X96_90 | 151.000 | 23.000  | 1.260 | 0.190 | 0.975 | 0.794 |
| X96_91 | 100.000 | 15.000  | 0.840 | 0.120 | 0.991 | 1.190 |
| X96_92 | 194.000 | 12.000  | 1.650 | 0.110 | 0.961 | 0.606 |
| X96_93 | 273.000 | 16.000  | 2.330 | 0.140 | 0.932 | 0.429 |
| X96_94 | 204.000 | 11.000  | 1.752 | 0.086 | 0.948 | 0.571 |
| X96_95 | 178.900 | 8.300   | 1.527 | 0.074 | 0.956 | 0.655 |
| X96_96 | 254.000 | 17.000  | 2.220 | 0.140 | 0.951 | 0.450 |

| Error 2σ | <sup>207</sup> Pb/ <sup>206</sup> Pb | Error 2σ | Correlation_38_ | Age <sup>206</sup> Pb/ <sup>23</sup> | Error 2σ | Age <sup>207</sup> Pb/ <sup>23</sup> |
|----------|--------------------------------------|----------|-----------------|--------------------------------------|----------|--------------------------------------|
| 0.115    | 0.112                                | 0.005    | 0.329           | 1929.822                             | 77.414   | 1888.022                             |
| 0.097    | 0.121                                | 0.007    | 0.321           | 1939.372                             | 66.303   | 1962.705                             |
| 0.124    | 0.118                                | 0.007    | 0.383           | 1867.398                             | 77.808   | 1911.473                             |
| 0.097    | 0.117                                | 0.006    | 0.307           | 1939.372                             | 66.303   | 1911.473                             |
| 0.126    | 0.123                                | 0.006    | 0.290           | 1963.186                             | 88.233   | 1972.939                             |
| 0.084    | 0.118                                | 0.007    | 0.188           | 1991.647                             | 60.520   | 2000.209                             |
| 0.098    | 0.123                                | 0.007    | 0.325           | 1862.571                             | 61.159   | 1929.851                             |
| 0.095    | 0.112                                | 0.007    | 0.357           | 1963.186                             | 66.175   | 1895.899                             |
| 0.107    | 0.122                                | 0.006    | 0.251           | 1986.912                             | 77.055   | 1983.071                             |
| 0.101    | 0.118                                | 0.006    | 0.255           | 1905.884                             | 66.484   | 1897.467                             |
| 0.107    | 0.113                                | 0.006    | 0.331           | 1991.647                             | 77.025   | 1903.716                             |
| 0.101    | 0.153                                | 0.012    | -0.133          | 2038.804                             | 76.729   | 2219.679                             |
| 0.110    | 0.113                                | 0.006    | 0.333           | 1963.186                             | 77.204   | 1875.289                             |
| 0.107    | 0.116                                | 0.007    | 0.260           | 1720.993                             | 56.242   | 1831.100                             |
| 0.118    | 0.116                                | 0.007    | 0.327           | 1716.055                             | 61.891   | 1810.825                             |
| 0.081    | 0.114                                | 0.005    | 0.311           | 1906.843                             | 53.183   | 1895.899                             |
| 0.099    | 0.115                                | 0.006    | 0.262           | 1929.822                             | 66.355   | 1888.022                             |
| 0.110    | 0.117                                | 0.006    | 0.398           | 1967.938                             | 77.174   | 1934.394                             |
| 0.087    | 0.120                                | 0.006    | 0.280           | 1958.430                             | 60.684   | 1929.851                             |
| 0.102    | 0.118                                | 0.007    | 0.400           | 1833.533                             | 61.304   | 1872.081                             |
| 0.111    | 0.111                                | 0.006    | 0.194           | 1896.284                             | 72.081   | 1852.616                             |
| 0.092    | 0.112                                | 0.006    | 0.375           | 1910.679                             | 60.920   | 1872.081                             |
| 0.101    | 0.117                                | 0.006    | 0.404           | 1910.679                             | 66.458   | 1895.899                             |
| 0.105    | 0.113                                | 0.006    | 0.015           | 2005.830                             | 76.936   | 1926.811                             |
| 0.085    | 0.118                                | 0.006    | 0.356           | 1896.284                             | 55.447   | 1914.559                             |
| 0.121    | 0.129                                | 0.006    | -0.165          | 1996.378                             | 87.995   | 2043.187                             |
| 0.096    | 0.109                                | 0.005    | 0.342           | 2019.983                             | 71.358   | 1919.171                             |
| 0.118    | 0.115                                | 0.005    | 0.433           | 1963.186                             | 82.719   | 1931.368                             |
| 0.109    | 0.118                                | 0.005    | 0.285           | 1848.068                             | 66.798   | 1854.253                             |
|          |                                      |          |                 |                                      |          |                                      |
| 0.691    | 0.053                                | 0.009    | -0.009          | 472.802                              | 24.852   | 489.847                              |
| 0.712    | 0.064                                | 0.010    | 0.264           | 518.765                              | 30.953   | 550.667                              |
| 0.791    | 0.055                                | 0.009    | 0.207           | 483.576                              | 29.797   | 452.177                              |
| 0.781    | 0.057                                | 0.009    | 0.403           | 505.666                              | 32.224   | 505.397                              |
| 0.604    | 0.062                                | 0.009    | 0.238           | 510.432                              | 25.398   | 544.746                              |
| 0.547    | 0.068                                | 0.010    | -0.064          | 522.333                              | 24.136   | 574.010                              |
| 0.679    | 0.064                                | 0.009    | 0.378           | 504.474                              | 27.889   | 552.436                              |
| 0.766    | 0.057                                | 0.009    | 0.256           | 510.432                              | 32.212   | 489.847                              |
| 0.726    | 0.053                                | 0.008    | 0.231           | 493.735                              | 28.532   | 449.572                              |
| 0.641    | 0.061                                | 0.007    | 0.201           | 529.462                              | 29.071   | 547.711                              |
| 0.795    | 0.062                                | 0.011    | 0.227           | 477.593                              | 29.190   | 482.298                              |
| 0.640    | 0.058                                | 0.008    | -0.023          | 453.604                              | 21.156   | 474.056                              |
| 0.716    | 0.062                                | 0.010    | 0.375           | 502.089                              | 29.134   | 520.712                              |
| 0.532    | 0.055                                | 0.008    | 0.047           | 516.385                              | 22.909   | 520.712                              |
| 0.746    | 0.061                                | 0.009    | 0.175           | 492.540                              | 29.155   | 496.719                              |
| 0.775    | 0.072                                | 0.010    | 0.352           | 497.913                              | 31.003   | 574.587                              |
| 0.721    | 0.048                                | 0.009    | 0.243           | 468.607                              | 25.481   | 393.948                              |
| 0.654    | 0.053                                | 0.007    | 0.187           | 479.388                              | 24.218   | 449.572                              |
| 0.531    | 0.055                                | 0.009    | 0.076           | 561.449                              | 27.147   | 532.800                              |



|       |       |       |        |          |         |          |
|-------|-------|-------|--------|----------|---------|----------|
| 0.696 | 0.059 | 0.009 | 0.353  | 487.761  | 26.684  | 508.479  |
| 0.686 | 0.060 | 0.009 | 0.325  | 491.346  | 26.677  | 504.162  |
| 0.737 | 0.059 | 0.008 | 0.010  | 435.553  | 22.432  | 457.368  |
| 0.672 | 0.056 | 0.009 | 0.179  | 473.401  | 24.229  | 442.373  |
| 0.627 | 0.061 | 0.008 | 0.306  | 512.814  | 26.632  | 527.982  |
| 0.669 | 0.053 | 0.008 | 0.130  | 518.765  | 29.095  | 463.175  |
| 1.024 | 0.056 | 0.009 | 0.223  | 386.563  | 24.395  | 406.953  |
| 1.023 | 0.044 | 0.008 | 0.171  | 435.553  | 31.155  | 385.648  |
| 0.789 | 0.054 | 0.009 | -0.183 | 469.207  | 27.966  | 470.868  |
| 0.928 | 0.043 | 0.007 | 0.160  | 456.607  | 31.104  | 385.648  |
| 0.262 | 0.058 | 0.002 | 0.300  | 499.703  | 10.540  | 505.397  |
| 0.204 | 0.057 | 0.002 | 0.134  | 512.814  | 8.671   | 510.323  |
| 0.221 | 0.060 | 0.002 | 0.218  | 493.735  | 8.684   | 513.390  |
| 0.274 | 0.056 | 0.002 | 0.081  | 502.089  | 11.158  | 498.585  |
| 0.206 | 0.057 | 0.002 | 0.074  | 492.540  | 8.064   | 489.847  |
| 0.211 | 0.058 | 0.002 | 0.309  | 521.738  | 9.284   | 521.320  |
| 0.283 | 0.057 | 0.002 | 0.354  | 494.929  | 11.164  | 499.827  |
| 0.241 | 0.057 | 0.002 | 0.128  | 504.474  | 9.916   | 496.719  |
| 0.259 | 0.060 | 0.002 | 0.163  | 516.385  | 11.145  | 520.104  |
| 0.250 | 0.059 | 0.002 | 0.029  | 496.123  | 9.922   | 506.014  |
| 0.252 | 0.056 | 0.002 | 0.301  | 478.790  | 9.315   | 484.191  |
| 0.252 | 0.058 | 0.002 | 0.041  | 494.332  | 9.924   | 496.719  |
| 0.235 | 0.059 | 0.002 | 0.314  | 526.492  | 10.517  | 520.712  |
| 0.306 | 0.059 | 0.002 | 0.283  | 513.409  | 13.006  | 519.496  |
| 0.259 | 0.057 | 0.002 | 0.442  | 472.802  | 9.319   | 474.692  |
| 0.227 | 0.059 | 0.002 | 0.331  | 519.954  | 9.904   | 525.565  |
| 0.234 | 0.055 | 0.002 | 0.221  | 512.219  | 9.910   | 494.849  |
| 0.238 | 0.058 | 0.002 | 0.197  | 508.050  | 9.913   | 513.390  |
| 0.285 | 0.057 | 0.002 | -0.009 | 505.666  | 11.774  | 501.687  |
| 0.265 | 0.058 | 0.002 | 0.121  | 496.720  | 10.542  | 497.341  |
| 0.283 | 0.057 | 0.002 | 0.455  | 494.929  | 11.164  | 501.067  |
| 0.244 | 0.057 | 0.002 | 0.422  | 516.385  | 10.526  | 510.323  |
| 0.345 | 0.058 | 0.002 | 0.170  | 449.396  | 11.204  | 459.953  |
| 0.202 | 0.057 | 0.001 | 0.005  | 549.028  | 9.881   | 538.791  |
| 0.282 | 0.059 | 0.002 | 0.398  | 482.380  | 10.554  | 496.096  |
| 0.387 | 0.060 | 0.002 | 0.373  | 436.758  | 11.838  | 463.175  |
| 0.370 | 0.059 | 0.002 | 0.165  | 457.208  | 12.441  | 461.243  |
| 0.246 | 0.059 | 0.002 | 0.119  | 515.195  | 10.527  | 526.774  |
| 0.217 | 0.058 | 0.002 | 0.362  | 531.243  | 9.895   | 529.792  |
| 0.110 | 0.837 | 0.030 | 0.318  | 2509.819 | 131.818 | 4089.085 |
| 0.122 | 0.817 | 0.020 | 0.026  | 3514.759 | 310.268 | 4512.187 |
| 1.111 | 0.720 | 0.046 | 0.010  | 917.758  | 155.959 | 2852.620 |
| 0.622 | 0.749 | 0.035 | -0.040 | 1110.532 | 129.956 | 3076.746 |
| 0.260 | 0.715 | 0.026 | 0.340  | 1115.956 | 54.912  | 3020.266 |
| 0.175 | 0.716 | 0.027 | 0.468  | 1256.462 | 47.292  | 3128.387 |
| 1.427 | 0.622 | 0.041 | 0.001  | 359.794  | 29.460  | 1864.016 |
| 0.351 | 0.814 | 0.040 | 0.165  | 982.290  | 56.694  | 2995.064 |
| 0.780 | 0.776 | 0.040 | 0.432  | 753.546  | 72.924  | 2694.057 |

|       |       |       |        |           |          |          |
|-------|-------|-------|--------|-----------|----------|----------|
| 0.118 | 0.809 | 0.017 | 0.136  | 2019.983  | 87.825   | 3804.791 |
| 0.152 | 0.808 | 0.028 | -0.119 | 2404.138  | 164.886  | 3988.319 |
| 0.349 | 0.596 | 0.016 | 0.258  | 870.622   | 43.953   | 2584.689 |
| 0.193 | 0.613 | 0.021 | 0.567  | 978.968   | 31.040   | 2738.819 |
| 0.110 | 0.802 | 0.022 | 0.474  | 1575.226  | 47.803   | 3507.883 |
| 0.107 | 0.824 | 0.022 | 0.693  | 2452.790  | 121.845  | 4033.281 |
| 0.340 | 0.751 | 0.034 | 0.140  | 1266.004  | 93.346   | 3196.886 |
|       |       |       |        |           |          |          |
| 0.070 | 0.852 | 0.023 | 0.406  | 4171.496  | 265.876  | 4769.089 |
| 0.045 | 0.830 | 0.017 | 0.462  | 5094.433  | 275.032  | 5016.208 |
| 0.016 | 0.842 | 0.017 | 0.481  | 7852.838  | 303.428  | 5699.475 |
| 0.015 | 0.855 | 0.018 | 0.179  | 9032.606  | 413.256  | 5979.467 |
| 0.023 | 0.840 | 0.035 | 0.064  | 13323.853 | 2124.093 | 6775.954 |
| 0.021 | 0.843 | 0.029 | -0.153 | 17414.093 | 5011.250 | 7504.492 |
| 0.039 | 0.820 | 0.030 | 0.195  | 7716.024  | 701.457  | 5695.763 |
| 0.028 | 0.822 | 0.026 | 0.165  | 15964.792 | 4833.377 | 7199.990 |
| 0.033 | 0.842 | 0.024 | 0.169  | 12066.412 | 2193.893 | 6578.169 |
| 0.017 | 0.861 | 0.029 | 0.244  | 15457.826 | 2627.830 | 7174.304 |
| 0.043 | 0.792 | 0.027 | 0.142  | 7637.647  | 740.212  | 5590.020 |
| 0.026 | 0.830 | 0.026 | 0.288  | 8434.055  | 593.508  | 5834.597 |
| 0.037 | 0.821 | 0.025 | 0.358  | 7230.798  | 558.902  | 5552.176 |
| 0.031 | 0.835 | 0.022 | 0.236  | 7498.152  | 511.238  | 5630.479 |
| 0.044 | 0.844 | 0.024 | 0.200  | 6728.793  | 548.543  | 5453.255 |
| 0.026 | 0.825 | 0.025 | 0.337  | 8185.402  | 543.562  | 5750.074 |
| 0.208 | 0.836 | 0.032 | -0.348 | 3644.247  | 575.407  | 4486.816 |
| 0.037 | 0.841 | 0.025 | 0.298  | 13404.941 | 3446.985 | 6788.710 |
| 0.024 | 0.843 | 0.026 | 0.232  | 10165.445 | 926.538  | 6175.782 |
| 0.040 | 0.839 | 0.035 | 0.334  | 10426.470 | 1677.526 | 6182.713 |
| 0.047 | 0.855 | 0.020 | 0.126  | 6885.757  | 612.868  | 5508.402 |
| 0.031 | 0.845 | 0.026 | 0.175  | 11174.368 | 1630.595 | 6427.091 |
| 0.022 | 0.823 | 0.032 | 0.534  | 16778.016 | 4563.620 | 7363.613 |
| 0.048 | 0.818 | 0.031 | 0.171  | 6402.912  | 527.299  | 5343.646 |
| 0.037 | 0.868 | 0.032 | 0.230  | 6796.532  | 472.486  | 5503.919 |
| 0.016 | 0.846 | 0.026 | 0.131  | 14092.192 | 1783.822 | 6930.456 |
| 0.040 | 0.868 | 0.041 | 0.185  | 8416.609  | 907.367  | 5847.491 |
| 0.085 | 0.808 | 0.051 | 0.385  | 3367.342  | 196.346  | 4441.792 |
| 0.060 | 0.838 | 0.034 | 0.116  | 7334.943  | 934.167  | 5560.708 |
| 0.129 | 0.824 | 0.034 | -0.015 | 3121.846  | 250.549  | 4319.636 |
| 0.165 | 0.814 | 0.032 | 0.216  | 3251.604  | 351.927  | 4385.257 |
| 0.058 | 0.829 | 0.026 | 0.177  | 6034.446  | 545.047  | 5238.417 |
| 0.224 | 0.842 | 0.061 | 0.340  | 3753.203  | 665.125  | 4569.030 |
| 0.071 | 0.813 | 0.022 | -0.024 | 5369.277  | 495.626  | 5080.922 |
| 0.082 | 0.837 | 0.027 | 0.388  | 4964.437  | 470.766  | 4957.914 |
| 0.025 | 0.833 | 0.033 | 0.546  | 9447.655  | 794.397  | 6044.822 |
| 0.016 | 0.812 | 0.025 | 0.395  | 11231.065 | 858.425  | 6375.104 |
| 0.016 | 0.847 | 0.025 | 0.314  | 14305.905 | 1919.085 | 6984.136 |
| 0.007 | 0.833 | 0.025 | 0.325  | 21751.289 | 4088.008 | 8204.850 |
| 0.024 | 0.857 | 0.033 | 0.116  | 14512.759 | 2902.552 | 6984.136 |
| 0.048 | 0.812 | 0.041 | 0.195  | 6282.415  | 494.978  | 5295.157 |
| 0.064 | 0.857 | 0.041 | -0.145 | 5562.546  | 487.230  | 5134.026 |

|       |       |       |        |           |          |          |
|-------|-------|-------|--------|-----------|----------|----------|
| 0.168 | 0.812 | 0.039 | 0.132  | 2562.017  | 210.001  | 4099.888 |
| 0.052 | 0.847 | 0.033 | 0.079  | 7907.896  | 984.385  | 5721.470 |
| 0.006 | 0.833 | 0.018 | 0.238  | 20405.963 | 2966.506 | 8026.677 |
| 0.029 | 0.816 | 0.035 | 0.426  | 9594.840  | 951.092  | 6083.632 |
| 0.081 | 0.841 | 0.036 | 0.376  | 5535.288  | 610.510  | 5165.859 |
| 0.167 | 0.805 | 0.063 | -0.001 | 5082.723  | 1016.545 | 5101.163 |
| 0.067 | 0.834 | 0.028 | 0.129  | 4400.269  | 287.658  | 4792.895 |
| 0.032 | 0.847 | 0.036 | -0.076 | 7676.954  | 569.905  | 5699.475 |
| 0.015 | 0.850 | 0.032 | -0.105 | 19407.709 | 5731.810 | 7944.810 |
| 0.101 | 0.856 | 0.036 | 0.052  | 7417.064  | 1613.898 | 5657.871 |
| 0.055 | 0.811 | 0.028 | 0.041  | 6885.757  | 721.022  | 5443.765 |
| 0.009 | 0.831 | 0.017 | -0.269 | 17542.597 | 2347.249 | 7504.492 |
| 0.072 | 0.864 | 0.041 | 0.462  | 4795.103  | 382.218  | 4950.193 |
| 0.038 | 0.848 | 0.027 | 0.228  | 8451.454  | 873.213  | 5860.224 |
| 0.125 | 0.800 | 0.034 | 0.299  | 3029.838  | 227.238  | 4279.927 |
| 0.042 | 0.846 | 0.025 | 0.209  | 11656.978 | 2514.250 | 6479.988 |
| 0.041 | 0.856 | 0.016 | 0.055  | 8293.144  | 886.290  | 5847.491 |
| 0.017 | 0.833 | 0.015 | 0.281  | 9851.590  | 600.374  | 6123.456 |
| 0.031 | 0.844 | 0.017 | 0.470  | 5662.409  | 245.492  | 5190.626 |
| 0.006 | 0.836 | 0.019 | -0.029 | 19984.479 | 2545.193 | 7894.883 |
| 0.039 | 0.858 | 0.015 | 0.043  | 8203.485  | 829.925  | 5808.308 |
| 0.021 | 0.839 | 0.017 | 0.303  | 8571.952  | 493.350  | 5869.669 |
| 0.005 | 0.858 | 0.011 | 0.087  | 15893.982 | 885.459  | 7263.882 |
| 0.076 | 0.834 | 0.028 | 0.118  | 4934.523  | 429.089  | 4995.665 |
| 1.304 | 0.759 | 0.016 | -0.129 | 316.363   | 20.755   | 1859.146 |
| 0.039 | 0.855 | 0.019 | 0.373  | 6330.885  | 417.004  | 5369.617 |
| 0.059 | 0.824 | 0.018 | -0.069 | 7735.470  | 1066.961 | 5657.871 |
| 0.277 | 0.830 | 0.047 | 0.413  | 2224.059  | 253.715  | 3902.873 |
| 0.042 | 0.844 | 0.020 | 0.380  | 5524.353  | 317.773  | 5146.241 |
| 0.005 | 0.852 | 0.017 | 0.247  | 16559.472 | 1016.930 | 7360.008 |
| 0.025 | 0.860 | 0.018 | 0.210  | 8416.609  | 563.193  | 5841.065 |
| 0.031 | 0.823 | 0.020 | 0.132  | 5366.474  | 218.955  | 5074.085 |
| 0.007 | 0.852 | 0.012 | 0.079  | 11699.112 | 432.457  | 6500.398 |
| 0.003 | 0.837 | 0.015 | 0.221  | 25371.407 | 3234.602 | 8790.302 |
| 0.022 | 0.841 | 0.018 | 0.034  | 10098.504 | 852.644  | 6180.408 |
| 0.080 | 0.817 | 0.021 | -0.179 | 7146.254  | 1161.706 | 5543.571 |
| 0.018 | 0.857 | 0.017 | -0.028 | 16730.087 | 3642.841 | 7405.897 |
| 0.018 | 0.849 | 0.013 | 0.106  | 10323.325 | 729.932  | 6229.949 |
| 0.021 | 0.813 | 0.016 | 0.283  | 8363.985  | 471.653  | 5791.524 |
| 0.149 | 0.846 | 0.032 | 0.158  | 6209.021  | 1494.764 | 5306.135 |
| 0.099 | 0.806 | 0.027 | 0.279  | 4344.653  | 415.497  | 4758.847 |
| 0.032 | 0.829 | 0.025 | 0.345  | 8968.779  | 861.240  | 5918.613 |
| 0.040 | 0.848 | 0.016 | -0.092 | 13323.853 | 3668.887 | 6930.456 |
| 0.015 | 0.856 | 0.018 | 0.223  | 10085.032 | 560.280  | 6207.729 |
| 0.107 | 0.847 | 0.021 | -0.024 | 5369.277  | 743.438  | 5114.436 |
| 0.019 | 0.837 | 0.019 | 0.294  | 8756.868  | 484.809  | 5879.027 |
| 0.024 | 0.837 | 0.016 | 0.119  | 8756.868  | 606.012  | 5912.622 |
| 0.007 | 0.848 | 0.014 | 0.025  | 17012.457 | 1439.516 | 7439.837 |
| 0.005 | 0.855 | 0.015 | -0.028 | 17344.496 | 1211.842 | 7504.492 |

|       |       |       |        |           |          |          |
|-------|-------|-------|--------|-----------|----------|----------|
| 0.011 | 0.847 | 0.014 | 0.061  | 12562.535 | 813.852  | 6653.305 |
| 0.010 | 0.848 | 0.014 | 0.064  | 17710.046 | 2547.335 | 7582.822 |
| 0.005 | 0.854 | 0.021 | 0.026  | 21270.161 | 3015.310 | 8149.969 |
| 0.129 | 0.862 | 0.048 | 0.409  | 3352.029  | 294.900  | 4484.366 |
| 0.386 | 0.803 | 0.026 | 0.259  | 1696.266  | 197.240  | 3559.484 |
| 0.013 | 0.854 | 0.013 | -0.121 | 22136.904 | 8854.762 | 8314.938 |
| 0.011 | 0.838 | 0.017 | 0.144  | 11442.078 | 630.482  | 6436.101 |
| 0.021 | 0.866 | 0.026 | 0.386  | 10426.470 | 877.475  | 6302.052 |
| 0.017 | 0.843 | 0.018 | -0.001 | 12016.633 | 1124.492 | 6546.485 |
| 0.068 | 0.828 | 0.017 | -0.217 | 6973.764  | 929.835  | 5490.351 |
| 0.177 | 0.829 | 0.019 | 0.087  | 4403.525  | 763.877  | 4763.515 |
| 0.024 | 0.847 | 0.014 | 0.008  | 10823.297 | 1117.083 | 6322.320 |
| 0.005 | 0.848 | 0.019 | 0.208  | 19896.771 | 2284.797 | 7924.305 |
| 0.115 | 0.820 | 0.024 | 0.030  | 5425.091  | 821.983  | 5094.461 |
| 0.033 | 0.860 | 0.017 | 0.190  | 7657.331  | 570.941  | 5706.860 |
| 0.111 | 0.835 | 0.038 | 0.382  | 3785.534  | 336.387  | 4602.325 |
| 0.025 | 0.839 | 0.019 | 0.172  | 14512.759 | 3073.290 | 6952.270 |
| 0.168 | 0.848 | 0.031 | -0.229 | 4069.439  | 601.167  | 4800.109 |
| 0.006 | 0.855 | 0.016 | 0.355  | 16830.329 | 1201.213 | 7433.139 |
| 0.031 | 0.851 | 0.013 | 0.180  | 6462.327  | 340.911  | 5384.886 |
| 0.024 | 0.857 | 0.016 | 0.453  | 5860.207  | 209.576  | 5234.910 |
| 0.011 | 0.859 | 0.017 | 0.071  | 14613.750 | 1334.666 | 7034.125 |
| 0.060 | 0.828 | 0.023 | 0.318  | 5278.958  | 399.669  | 5053.291 |
| 0.162 | 0.821 | 0.026 | 0.127  | 2173.642  | 140.934  | 3920.120 |
| 0.069 | 0.842 | 0.019 | 0.204  | 3173.275  | 139.704  | 4374.383 |
| 0.791 | 0.790 | 0.049 | 0.420  | 928.931   | 113.869  | 2917.769 |
| 0.120 | 0.837 | 0.023 | 0.204  | 2911.925  | 198.888  | 4270.888 |
| 0.025 | 0.874 | 0.020 | 0.429  | 7945.594  | 490.469  | 5767.551 |
| 0.053 | 0.847 | 0.022 | 0.064  | 6751.452  | 656.898  | 5467.325 |
| 0.007 | 0.853 | 0.013 | 0.197  | 19279.418 | 2652.195 | 7824.250 |
| 0.097 | 0.830 | 0.027 | 0.206  | 3640.583  | 268.607  | 4534.607 |
| 0.183 | 0.827 | 0.021 | 0.167  | 4690.080  | 920.483  | 4902.588 |
| 0.039 | 0.844 | 0.044 | 0.334  | 7396.631  | 619.253  | 5598.242 |
| 0.028 | 0.828 | 0.035 | 0.191  | 12814.661 | 2237.481 | 6695.856 |
| 0.060 | 0.842 | 0.024 | 0.048  | 5507.915  | 448.793  | 5121.008 |
| 0.088 | 0.810 | 0.030 | 0.227  | 2887.258  | 143.085  | 4224.445 |
| 0.012 | 0.864 | 0.017 | 0.000  | 13611.117 | 1199.878 | 6864.411 |
| 0.045 | 0.851 | 0.026 | -0.226 | 8520.586  | 1053.454 | 5853.877 |
| 0.010 | 0.840 | 0.017 | 0.217  | 14471.916 | 1165.984 | 7022.108 |
| 0.062 | 0.846 | 0.025 | -0.113 | 6426.744  | 676.499  | 5399.929 |
| 0.050 | 0.839 | 0.019 | 0.103  | 9251.149  | 1474.402 | 5982.276 |
| 0.181 | 0.819 | 0.029 | 0.043  | 3717.089  | 524.205  | 4546.212 |
| 0.064 | 0.833 | 0.020 | -0.126 | 5855.011  | 553.852  | 5238.417 |
| 0.083 | 0.826 | 0.024 | -0.150 | 4436.001  | 362.946  | 4835.431 |
| 0.043 | 0.858 | 0.014 | -0.321 | 10859.277 | 2053.121 | 6390.231 |
| 0.008 | 0.838 | 0.018 | -0.088 | 15046.471 | 1130.100 | 7076.053 |
| 0.310 | 0.822 | 0.022 | -0.066 | 2841.787  | 487.310  | 4238.602 |
| 2.653 | 0.766 | 0.042 | 0.139  | 436.156   | 81.000   | 2160.970 |
| 0.053 | 0.840 | 0.024 | 0.212  | 3916.772  | 173.350  | 4640.888 |
| 0.025 | 0.834 | 0.016 | 0.070  | 10652.683 | 1110.706 | 6270.871 |

|       |       |       |        |          |          |          |
|-------|-------|-------|--------|----------|----------|----------|
| 0.189 | 0.834 | 0.025 | 0.047  | 8936.628 | 5064.089 | 5979.467 |
| 0.056 | 0.859 | 0.018 | 0.288  | 5802.813 | 476.944  | 5226.679 |
| 0.019 | 0.831 | 0.016 | 0.159  | 8605.970 | 461.034  | 5857.055 |
| 0.120 | 0.855 | 0.026 | -0.126 | 5256.179 | 792.598  | 5101.163 |
| 0.170 | 0.836 | 0.017 | -0.043 | 3930.801 | 561.543  | 4686.115 |
| 0.040 | 0.849 | 0.020 | 0.444  | 6282.415 | 418.828  | 5354.114 |
| 0.026 | 0.841 | 0.018 | 0.348  | 7754.858 | 465.957  | 5699.475 |
| 0.028 | 0.855 | 0.014 | -0.145 | 6525.885 | 320.335  | 5404.894 |
| 0.032 | 0.845 | 0.015 | 0.399  | 5976.038 | 289.605  | 5272.276 |
| 0.028 | 0.838 | 0.018 | -0.063 | 7538.317 | 475.389  | 5626.505 |

| Error 2σ | alAge <sup>207</sup> Pb/ <sup>206</sup> Pb | Error 2σ | alAge 207Pb c | Error 2σ |
|----------|--------------------------------------------|----------|---------------|----------|
| 101.020  | 1835.353                                   | 86.697   | 1943.094      | 78.102   |
| 89.667   | 1966.596                                   | 105.906  | 1935.338      | 67.059   |
| 102.952  | 1927.673                                   | 109.360  | 1859.215      | 77.441   |
| 99.520   | 1910.892                                   | 94.728   | 1943.515      | 67.073   |
| 92.378   | 2000.193                                   | 95.944   | 1957.502      | 88.297   |
| 119.948  | 1923.116                                   | 111.012  | 2002.218      | 62.645   |
| 108.533  | 1998.748                                   | 107.337  | 1843.730      | 61.018   |
| 103.980  | 1832.121                                   | 109.600  | 1982.234      | 68.169   |
| 101.612  | 1979.834                                   | 91.177   | 1988.019      | 77.816   |
| 100.413  | 1929.190                                   | 96.296   | 1902.590      | 66.723   |
| 100.014  | 1843.404                                   | 99.776   | 2013.927      | 79.029   |
| 191.061  | 2379.728                                   | 186.645  | 1974.421      | 79.069   |
| 101.842  | 1846.612                                   | 98.137   | 1980.208      | 78.631   |
| 111.961  | 1890.811                                   | 106.225  | 1701.423      | 55.434   |
| 113.405  | 1901.658                                   | 120.896  | 1694.696      | 61.011   |
| 83.184   | 1870.454                                   | 88.291   | 1911.893      | 53.947   |
| 107.986  | 1881.450                                   | 101.347  | 1936.721      | 67.328   |
| 104.836  | 1906.282                                   | 102.910  | 1977.164      | 78.400   |
| 94.966   | 1957.705                                   | 92.914   | 1958.539      | 61.563   |
| 98.531   | 1930.704                                   | 110.979  | 1820.782      | 61.265   |
| 110.444  | 1819.120                                   | 98.154   | 1906.697      | 72.701   |
| 95.012   | 1836.967                                   | 101.418  | 1920.835      | 62.019   |
| 90.116   | 1917.017                                   | 97.974   | 1909.782      | 66.873   |
| 115.541  | 1843.404                                   | 89.962   | 2030.610      | 78.972   |
| 89.049   | 1930.704                                   | 89.762   | 1891.464      | 55.783   |
| 138.735  | 2087.113                                   | 103.386  | 1981.528      | 88.125   |
| 88.787   | 1784.441                                   | 83.416   | 2055.776      | 73.874   |
| 101.651  | 1878.317                                   | 88.276   | 1975.708      | 83.652   |
| 85.417   | 1926.156                                   | 88.146   | 1837.682      | 66.131   |
|          |                                            |          |               |          |
| 86.908   | 328.797                                    | 58.315   | 474.807       | 24.993   |
| 84.130   | 741.630                                    | 115.880  | 514.845       | 30.643   |
| 75.766   | 408.153                                    | 68.397   | 484.679       | 29.689   |
| 76.789   | 495.398                                    | 74.613   | 505.828       | 31.924   |
| 76.725   | 670.656                                    | 98.594   | 507.727       | 25.305   |
| 83.080   | 856.315                                    | 120.340  | 516.186       | 24.046   |
| 71.060   | 751.514                                    | 102.851  | 500.248       | 27.548   |
| 79.008   | 475.982                                    | 79.050   | 510.979       | 32.022   |
| 61.342   | 345.831                                    | 51.810   | 495.907       | 28.410   |
| 67.411   | 635.704                                    | 76.201   | 527.615       | 28.659   |
| 77.739   | 674.109                                    | 119.600  | 474.507       | 29.067   |
| 72.503   | 529.762                                    | 76.724   | 452.525       | 21.169   |
| 85.490   | 674.109                                    | 108.727  | 499.234       | 28.947   |
| 74.610   | 424.372                                    | 60.625   | 517.840       | 22.964   |
| 61.401   | 632.166                                    | 88.378   | 490.303       | 28.817   |
| 72.484   | 977.437                                    | 130.870  | 489.197       | 30.331   |
| 65.658   | 94.333                                     | 17.134   | 473.416       | 25.657   |
| 61.342   | 320.212                                    | 44.272   | 481.633       | 24.165   |
| 84.939   | 424.372                                    | 70.601   | 563.829       | 27.287   |

|         |          |         |         |         |
|---------|----------|---------|---------|---------|
| 86.050  | 555.987  | 89.034  | 486.705 | 26.613  |
| 72.135  | 585.440  | 84.618  | 489.864 | 26.494  |
| 61.090  | 559.699  | 72.342  | 433.854 | 22.256  |
| 72.919  | 464.219  | 77.507  | 473.534 | 24.308  |
| 65.030  | 646.271  | 81.312  | 510.567 | 26.332  |
| 66.511  | 333.072  | 47.044  | 521.635 | 28.946  |
| 66.037  | 448.399  | 73.797  | 385.845 | 24.292  |
| 62.605  | -88.460  | -14.942 | 441.441 | 31.179  |
| 79.808  | 383.513  | 64.272  | 470.410 | 27.910  |
| 61.770  | -150.333 | -23.956 | 463.663 | 31.142  |
| 17.238  | 533.535  | 17.448  | 499.169 | 10.352  |
| 17.193  | 499.252  | 14.838  | 513.032 | 8.537   |
| 17.165  | 599.964  | 19.031  | 492.045 | 8.535   |
| 18.087  | 448.399  | 12.834  | 502.918 | 10.963  |
| 15.011  | 479.884  | 13.542  | 492.734 | 7.943   |
| 12.431  | 522.189  | 14.455  | 521.731 | 9.120   |
| 14.932  | 506.935  | 13.247  | 494.743 | 10.944  |
| 18.105  | 475.982  | 16.819  | 504.920 | 9.773   |
| 20.991  | 599.964  | 22.035  | 514.988 | 10.941  |
| 22.716  | 552.267  | 20.734  | 495.238 | 9.770   |
| 16.642  | 460.278  | 16.380  | 479.062 | 9.188   |
| 17.318  | 533.535  | 17.448  | 493.720 | 9.754   |
| 15.544  | 548.538  | 15.003  | 526.122 | 10.311  |
| 15.554  | 548.538  | 15.940  | 512.835 | 12.732  |
| 14.336  | 495.398  | 15.617  | 472.470 | 9.168   |
| 17.829  | 578.128  | 17.549  | 518.981 | 9.719   |
| 17.335  | 424.372  | 13.813  | 513.596 | 9.768   |
| 18.725  | 525.980  | 16.352  | 507.762 | 9.741   |
| 18.058  | 506.935  | 16.780  | 505.646 | 11.561  |
| 18.099  | 518.389  | 17.968  | 496.382 | 10.366  |
| 18.064  | 479.884  | 18.620  | 495.160 | 10.995  |
| 17.193  | 487.660  | 17.998  | 516.849 | 10.371  |
| 17.660  | 537.299  | 19.387  | 448.161 | 11.000  |
| 14.624  | 503.098  | 10.536  | 549.826 | 9.685   |
| 14.174  | 567.096  | 17.301  | 481.080 | 10.346  |
| 16.027  | 585.440  | 19.679  | 434.701 | 11.592  |
| 17.648  | 548.538  | 15.003  | 455.895 | 12.176  |
| 15.493  | 570.782  | 15.453  | 514.277 | 10.311  |
| 14.695  | 518.389  | 14.375  | 531.460 | 9.716   |
| 222.636 | 4986.038 | 178.711 | -6.510  | 121.171 |
| 343.377 | 4951.665 | 121.216 | 176.223 | 124.623 |
| 493.723 | 4771.159 | 304.824 | 153.718 | 62.167  |
| 421.686 | 4827.717 | 225.594 | 144.546 | 56.037  |
| 160.929 | 4761.163 | 173.133 | 200.933 | 41.233  |
| 118.933 | 4763.168 | 179.617 | 229.490 | 47.770  |
| 198.074 | 4560.250 | 300.595 | 101.792 | 20.785  |
| 198.568 | 4946.432 | 243.068 | 31.646  | 54.559  |
| 265.324 | 4878.312 | 251.459 | 63.973  | 41.217  |

|          |          |         |            |           |
|----------|----------|---------|------------|-----------|
| 156.235  | 4937.664 | 103.758 | 97.770     | 55.676    |
| 296.321  | 4935.904 | 171.046 | 131.288    | 105.298   |
| 131.984  | 4498.277 | 120.759 | 294.026    | 24.003    |
| 87.072   | 4539.118 | 155.500 | 312.456    | 29.273    |
| 103.005  | 4925.292 | 135.108 | 87.761     | 52.108    |
| 147.087  | 4963.796 | 132.529 | 57.886     | 87.873    |
| 243.709  | 4831.531 | 218.738 | 165.305    | 61.010    |
| 329.357  | 5011.250 | 135.280 | -214.530   | 189.955   |
| 245.751  | 4974.107 | 101.879 | 192.279    | 179.259   |
| 208.772  | 4994.495 | 100.839 | 949.020    | 317.425   |
| 298.973  | 5016.235 | 105.605 | -484.607   | 526.826   |
| 1115.030 | 4991.118 | 207.963 | -6698.243  | 6170.266  |
| 2177.229 | 4996.180 | 171.873 | 0.000      | 4155.742  |
| 544.448  | 4956.877 | 181.349 | 0.000      | 569.772   |
| 2039.997 | 4960.341 | 156.896 | 0.000      | 3281.484  |
| 1214.431 | 4994.495 | 142.361 | -4742.728  | 2748.354  |
| 1226.377 | 5026.151 | 169.290 | -2406.996  | 3450.406  |
| 547.594  | 4907.418 | 167.298 | 1609.095   | 472.860   |
| 430.115  | 4974.107 | 155.815 | 0.000      | 572.979   |
| 399.945  | 4958.610 | 150.993 | 2111.130   | 389.962   |
| 397.446  | 4982.640 | 131.279 | 1294.628   | 357.764   |
| 458.685  | 4997.862 | 142.119 | -30.103    | 380.375   |
| 340.597  | 4965.520 | 150.470 | 0.000      | 523.338   |
| 711.324  | 4984.340 | 190.788 | 2.541      | 204.962   |
| 1782.036 | 4992.807 | 148.419 | -11193.841 | 11797.549 |
| 565.289  | 4996.180 | 154.093 | -728.047   | 954.297   |
| 913.355  | 4989.427 | 208.141 | -353.954   | 1248.184  |
| 487.469  | 5016.235 | 117.339 | -890.326   | 402.674   |
| 998.495  | 4999.543 | 153.832 | -1334.809  | 1283.412  |
| 1984.520 | 4962.070 | 192.936 | 0.000      | 4007.151  |
| 417.472  | 4953.404 | 187.721 | 1189.794   | 379.418   |
| 366.928  | 5037.628 | 185.719 | -2082.530  | 754.107   |
| 828.642  | 5001.222 | 153.702 | 0.000      | 2939.200  |
| 592.151  | 5037.628 | 237.952 | -6614.516  | 3134.434  |
| 317.271  | 4935.904 | 311.548 | 235.227    | 277.108   |
| 654.201  | 4987.733 | 202.366 | 809.326    | 536.915   |
| 404.577  | 4963.796 | 204.817 | 88.365     | 175.106   |
| 491.196  | 4946.432 | 194.454 | 173.780    | 172.160   |
| 454.198  | 4972.394 | 155.950 | 486.031    | 318.436   |
| 821.399  | 4994.495 | 361.834 | -61.574    | 401.548   |
| 514.958  | 4944.683 | 133.804 | 673.073    | 228.725   |
| 416.313  | 4986.038 | 160.840 | 22.991     | 265.778   |
| 440.768  | 4979.233 | 197.257 | 192.377    | 902.121   |
| 467.348  | 4942.932 | 152.184 | #NUM!      | #VALUE!   |
| 936.018  | 5002.898 | 147.665 | 0.000      | 3391.160  |
| 1600.327 | 4979.233 | 149.437 | 0.000      | 6066.830  |
| 1368.027 | 5019.549 | 193.285 | -1638.437  | 2947.108  |
| 405.094  | 4942.932 | 249.582 | 1328.142   | 468.519   |
| 526.567  | 5019.549 | 240.142 | -585.610   | 522.277   |



|          |          |         |           |          |
|----------|----------|---------|-----------|----------|
| 397.476  | 4942.932 | 237.407 | 124.561   | 155.375  |
| 635.719  | 5002.898 | 194.918 | 276.740   | 631.691  |
| 1214.368 | 4979.233 | 107.594 | #VALUE!   | #VALUE!  |
| 594.641  | 4949.923 | 212.313 | 3187.661  | 1727.165 |
| 577.549  | 4992.807 | 213.723 | -48.540   | 412.158  |
| 1486.432 | 4930.609 | 385.874 | 718.123   | 565.258  |
| 340.502  | 4980.938 | 167.226 | 47.785    | 231.064  |
| 480.176  | 5002.898 | 212.638 | 92.096    | 670.812  |
| 2478.781 | 5007.915 | 188.533 | #VALUE!   | #VALUE!  |
| 1209.316 | 5017.893 | 211.033 | -1172.322 | 839.330  |
| 564.919  | 4941.178 | 170.596 | 2176.854  | 428.209  |
| 1019.128 | 4975.818 | 101.792 | #VALUE!   | #VALUE!  |
| 418.862  | 5031.082 | 238.743 | -552.576  | 420.327  |
| 586.022  | 5004.573 | 159.344 | 764.786   | 554.463  |
| 340.084  | 4921.737 | 209.174 | 246.466   | 164.433  |
|          |          |         |           |          |
| 1317.964 | 5001.222 | 147.790 | -1776.273 | 1495.844 |
| 647.665  | 5017.893 | 93.792  | -1331.355 | 504.329  |
| 339.372  | 4979.233 | 89.662  | 219.362   | 491.529  |
| 213.917  | 4997.862 | 100.668 | -142.844  | 222.684  |
| 928.810  | 4984.340 | 113.280 | -66.077   | 3618.676 |
| 592.295  | 5021.203 | 87.783  | -1859.514 | 538.210  |
| 327.102  | 4989.427 | 101.097 | 3438.879  | 1001.142 |
| 409.233  | 5021.203 | 64.374  | -2264.366 | 1667.933 |
| 477.527  | 4980.938 | 167.226 | 84.741    | 269.386  |
| 127.728  | 4846.679 | 102.170 | 32.173    | 7.522    |
| 354.340  | 5016.235 | 111.472 | -722.033  | 325.290  |
| 755.822  | 4963.796 | 108.432 | 3106.419  | 756.651  |
| 418.470  | 4974.107 | 281.666 | 24.267    | 159.822  |
| 277.030  | 4997.862 | 118.433 | -143.222  | 245.657  |
| 403.360  | 5011.250 | 99.990  | -1798.165 | 2369.308 |
| 372.042  | 5024.504 | 105.164 | -2622.357 | 714.560  |
| 196.750  | 4962.070 | 120.585 | 424.705   | 212.524  |
| 259.152  | 5011.250 | 70.581  | -3121.563 | 1012.100 |
| 1131.274 | 4986.038 | 89.356  | #VALUE!   | #VALUE!  |
| 534.978  | 4992.807 | 106.862 | -511.807  | 662.611  |
| 947.619  | 4951.665 | 127.277 | 2259.699  | 483.485  |
| 1612.168 | 5019.549 | 99.571  | #VALUE!   | #VALUE!  |
| 445.962  | 5006.245 | 76.656  | -443.475  | 529.363  |
| 329.284  | 4944.683 | 97.312  | 1097.356  | 349.049  |
| 1233.318 | 5001.222 | 189.172 | -216.036  | 454.700  |
| 420.549  | 4932.376 | 165.228 | 444.503   | 208.108  |
| 523.771  | 4972.394 | 149.952 | 161.842   | 638.826  |
| 2410.594 | 5004.573 | 94.426  | #VALUE!   | #VALUE!  |
| 344.109  | 5017.893 | 105.516 | 1890.887  | 520.857  |
| 735.409  | 5002.898 | 124.039 | -228.930  | 251.663  |
| 306.575  | 4986.038 | 113.184 | 0.000     | 468.653  |
| 421.077  | 4986.038 | 95.313  | 0.000     | 478.158  |
| 636.302  | 5004.573 | 82.623  | 0.000     | 2066.125 |
| 555.888  | 5016.235 | 88.004  | -2549.439 | 2744.870 |

|          |          |         |            |           |
|----------|----------|---------|------------|-----------|
| 437.217  | 5002.898 | 82.693  | 0.000      | 1055.176  |
| 1083.260 | 5004.573 | 82.623  | 0.000      | 2818.139  |
| 1198.525 | 5014.575 | 123.309 | 0.000      | 10412.026 |
| 367.301  | 5027.797 | 279.970 | -228.966   | 284.118   |
| 341.622  | 4927.067 | 159.531 | 93.914     | 66.586    |
| 3233.587 | 5014.575 | 76.334  | #VALUE!    | #VALUE!   |
| 341.740  | 4987.733 | 101.183 | -1021.769  | 884.809   |
| 534.720  | 5034.359 | 151.147 | 0.000      | 1339.931  |
| 613.084  | 4996.180 | 106.680 | #VALUE!    | #VALUE!   |
| 766.671  | 4970.679 | 102.055 | 1222.915   | 293.775   |
| 793.919  | 4972.394 | 113.963 | 124.703    | 163.208   |
| 651.011  | 5002.898 | 82.693  | -1459.899  | 742.932   |
| 905.635  | 5004.573 | 112.131 | 0.000      | 5013.396  |
| 747.188  | 4956.877 | 145.079 | 521.873    | 260.080   |
| 394.292  | 5024.504 | 99.322  | -1946.945  | 522.533   |
| 405.205  | 4982.640 | 226.755 | 15.002     | 252.858   |
| 1405.246 | 4989.427 | 112.991 | #VALUE!    | #VALUE!   |
| 728.588  | 5004.573 | 182.950 | -149.583   | 238.202   |
| 541.487  | 5016.235 | 93.871  | -2301.500  | 2550.459  |
| 296.169  | 5009.583 | 76.527  | -505.171   | 239.257   |
| 176.116  | 5019.549 | 93.714  | -676.530   | 248.669   |
| 669.588  | 5022.854 | 99.405  | -1848.490  | 1724.495  |
| 386.015  | 4970.679 | 138.074 | 275.461    | 240.799   |
| 261.341  | 4958.610 | 157.033 | 60.226     | 88.335    |
| 196.937  | 4994.495 | 112.702 | -46.916    | 108.848   |
| 349.433  | 4903.814 | 304.161 | 62.278     | 62.541    |
| 290.756  | 4986.038 | 137.012 | -7.602     | 114.234   |
| 316.030  | 5047.387 | 115.501 | -7166.158  | 1711.174  |
| 529.096  | 5002.898 | 129.945 | -237.187   | 368.255   |
| 1092.575 | 5012.914 | 76.398  | 0.000      | 4955.393  |
| 348.005  | 4974.107 | 161.808 | 62.705     | 172.930   |
| 1027.962 | 4968.962 | 126.177 | 190.786    | 193.534   |
| 498.629  | 4997.862 | 260.552 | 261.931    | 743.369   |
| 1100.689 | 4970.679 | 210.113 | 0.000      | 1909.128  |
| 399.040  | 4994.495 | 142.361 | -80.861    | 283.222   |
| 234.319  | 4939.422 | 182.942 | 164.704    | 139.205   |
| 629.105  | 5031.082 | 98.991  | #VALUE!    | #VALUE!   |
| 773.154  | 5009.583 | 153.054 | 139.261    | 589.268   |
| 585.757  | 4991.118 | 101.011 | 0.000      | 1570.644  |
| 638.415  | 5001.222 | 147.790 | -204.650   | 379.508   |
| 961.141  | 4989.427 | 112.991 | #VALUE!    | #VALUE!   |
| 627.064  | 4955.142 | 175.457 | 178.818    | 187.171   |
| 484.478  | 4979.233 | 119.549 | 272.266    | 249.315   |
| 458.532  | 4967.242 | 144.327 | 173.975    | 198.828   |
| 1183.376 | 5021.203 | 81.931  | #NUM!      | #VALUE!   |
| 533.036  | 4987.733 | 107.135 | -10115.085 | 7631.405  |
| 728.510  | 4960.341 | 132.759 | 86.631     | 105.524   |
| 379.630  | 4859.795 | 266.464 | 41.066     | 25.376    |
| 223.306  | 4991.118 | 142.603 | -41.827    | 174.735   |
| 666.280  | 4980.938 | 95.558  | #VALUE!    | #VALUE!   |

|          |          |         |          |         |
|----------|----------|---------|----------|---------|
| 3321.926 | 4980.938 | 149.309 | 39.586   | 643.188 |
| 427.915  | 5022.854 | 105.252 | -743.060 | 278.708 |
| 312.131  | 4975.818 | 95.804  | 105.023  | 407.670 |
| 776.998  | 5016.235 | 152.540 | -445.224 | 312.337 |
| 702.917  | 4984.340 | 101.356 | 6.008    | 129.634 |
| 331.182  | 5006.245 | 117.933 | -372.809 | 311.637 |
| 334.035  | 4992.807 | 106.862 | 954.149  | 327.702 |
| 291.440  | 5016.235 | 82.137  | -780.551 | 271.038 |
| 244.605  | 4999.543 | 88.749  | -176.235 | 220.322 |
| 376.577  | 4987.733 | 107.135 | 1034.133 | 310.733 |

| Sample     | $^{207}\text{Pb}/^{235}\text{U}$ | Error $2\sigma$ | $^{206}\text{Pb}/^{238}\text{U}$ | Error $2\sigma$ | rrelation_6_38 | $^{238}\text{U}/^{206}\text{Pb}$ |
|------------|----------------------------------|-----------------|----------------------------------|-----------------|----------------|----------------------------------|
| WRS_1      | 0.662                            | 0.030           | 0.085                            | 0.002           | 0.088          | 11.779                           |
| WRS_2      | 0.660                            | 0.031           | 0.085                            | 0.002           | 0.028          | 11.806                           |
| WRS_3      | 0.674                            | 0.033           | 0.084                            | 0.002           | 0.261          | 11.905                           |
| WRS_4      | 0.644                            | 0.036           | 0.084                            | 0.002           | 0.206          | 11.933                           |
| WRS_5      | 0.654                            | 0.028           | 0.084                            | 0.002           | 0.011          | 11.862                           |
| WRS_6      | 0.669                            | 0.032           | 0.084                            | 0.002           | 0.010          | 11.947                           |
| WRS_7      | 0.661                            | 0.030           | 0.084                            | 0.002           | 0.127          | 11.919                           |
| WRS_8      | 0.661                            | 0.031           | 0.083                            | 0.002           | 0.010          | 12.077                           |
| WRS_9      | 0.670                            | 0.030           | 0.084                            | 0.002           | 0.010          | 11.933                           |
| WRS_10     | 0.674                            | 0.034           | 0.083                            | 0.002           | 0.230          | 11.990                           |
| WRS_11     | 0.682                            | 0.031           | 0.084                            | 0.002           | 0.010          | 11.962                           |
| WRS_12     | 0.684                            | 0.032           | 0.086                            | 0.002           | 0.010          | 11.696                           |
| WRS_13     | 0.710                            | 0.034           | 0.087                            | 0.002           | 0.010          | 11.547                           |
| WRS_14     | 0.672                            | 0.029           | 0.085                            | 0.002           | 0.058          | 11.737                           |
| WRS_15     | 0.667                            | 0.032           | 0.085                            | 0.002           | 0.087          | 11.806                           |
| WRS_16     | 0.711                            | 0.040           | 0.086                            | 0.002           | 0.010          | 11.669                           |
| WRS_17     | 0.684                            | 0.037           | 0.087                            | 0.002           | 0.241          | 11.455                           |
| WRS_18     | 0.679                            | 0.040           | 0.086                            | 0.002           | 0.171          | 11.614                           |
| WRS_19     | 0.682                            | 0.045           | 0.084                            | 0.002           | 0.192          | 11.919                           |
| WRS_20     | 0.675                            | 0.035           | 0.086                            | 0.002           | 0.076          | 11.628                           |
| ZA16_84_1  | 0.769                            | 0.048           | 0.049                            | 0.002           | 0.332          | 20.408                           |
| ZA16_84_2  | 0.345                            | 0.014           | 0.047                            | 0.001           | 0.163          | 21.057                           |
| ZA16_84_3  | 0.332                            | 0.013           | 0.046                            | 0.001           | 0.349          | 21.978                           |
| ZA16_84_5  | 0.395                            | 0.023           | 0.048                            | 0.001           | 0.144          | 20.964                           |
| ZA16_84_6  | 0.484                            | 0.034           | 0.048                            | 0.001           | 0.335          | 21.008                           |
| ZA16_84_7  | 0.149                            | 0.010           | 0.015                            | 0.001           | 0.862          | 64.935                           |
| ZA16_84_8  | 0.334                            | 0.015           | 0.047                            | 0.001           | 0.150          | 21.227                           |
| ZA16_84_9  | 0.319                            | 0.020           | 0.048                            | 0.001           | 0.010          | 20.877                           |
| ZA16_84_10 | 0.340                            | 0.014           | 0.048                            | 0.001           | 0.318          | 21.008                           |
| ZA16_84_11 | 0.327                            | 0.014           | 0.047                            | 0.001           | 0.044          | 21.322                           |
| ZA16_84_13 | 0.353                            | 0.018           | 0.048                            | 0.001           | 0.116          | 20.964                           |
| ZA16_84_14 | 0.356                            | 0.019           | 0.048                            | 0.001           | 0.107          | 21.008                           |
| ZA16_84_15 | 0.514                            | 0.044           | 0.050                            | 0.002           | 0.725          | 19.960                           |
| ZA16_84_16 | 0.342                            | 0.021           | 0.046                            | 0.001           | 0.129          | 21.882                           |
| ZA16_84_17 | 0.391                            | 0.016           | 0.048                            | 0.001           | 0.641          | 20.790                           |
| ZA16_84_18 | 0.625                            | 0.034           | 0.048                            | 0.002           | 0.575          | 20.747                           |
| ZA16_84_19 | 0.204                            | 0.010           | 0.017                            | 0.002           | 0.148          | 60.241                           |
| ZA16_84_20 | 0.466                            | 0.020           | 0.045                            | 0.001           | 0.037          | 22.026                           |
| ZA16_84_21 | 0.665                            | 0.044           | 0.051                            | 0.002           | 0.220          | 19.763                           |
| ZA16_84_22 | 0.658                            | 0.057           | 0.051                            | 0.002           | 0.508          | 19.763                           |
| ZA16_84_23 | 0.380                            | 0.021           | 0.048                            | 0.001           | 0.194          | 20.964                           |
| ZA16_84_24 | 0.348                            | 0.012           | 0.048                            | 0.001           | 0.010          | 20.708                           |
| ZA16_84_25 | 0.652                            | 0.052           | 0.049                            | 0.001           | 0.735          | 20.450                           |
| ZA16_84_26 | 0.402                            | 0.010           | 0.048                            | 0.001           | 0.376          | 20.799                           |
| ZA16_84_27 | 0.445                            | 0.018           | 0.047                            | 0.001           | 0.034          | 21.277                           |
| ZA16_84_29 | 2.510                            | 0.150           | 0.065                            | 0.002           | 0.725          | 15.291                           |
| ZA16_84_30 | 0.162                            | 0.006           | 0.015                            | 0.001           | 0.310          | 65.833                           |
| ZA16_84_31 | 0.344                            | 0.021           | 0.041                            | 0.002           | 0.347          | 24.691                           |

|            |       |       |       |       |       |        |
|------------|-------|-------|-------|-------|-------|--------|
| ZA16_84_32 | 0.335 | 0.021 | 0.048 | 0.002 | 0.213 | 21.008 |
| ZA16_84_33 | 0.659 | 0.079 | 0.048 | 0.002 | 0.284 | 20.747 |
| ZA16_84_34 | 0.274 | 0.014 | 0.032 | 0.002 | 0.776 | 30.960 |
| ZA16_84_35 | 0.329 | 0.008 | 0.047 | 0.001 | 0.214 | 21.093 |
| ZA16_84_36 | 0.310 | 0.010 | 0.041 | 0.001 | 0.442 | 24.396 |
| ZA16_84_37 | 0.393 | 0.018 | 0.044 | 0.001 | 0.308 | 22.779 |
| ZA16_84_38 | 0.336 | 0.013 | 0.048 | 0.001 | 0.299 | 20.833 |
| ZA16_84_39 | 0.343 | 0.012 | 0.046 | 0.001 | 0.227 | 21.834 |
| ZA16_84_40 | 0.475 | 0.031 | 0.048 | 0.002 | 0.250 | 20.704 |
| ZA16_84_41 | 0.530 | 0.042 | 0.048 | 0.002 | 0.649 | 20.661 |
| ZA16_84_42 | 0.479 | 0.026 | 0.046 | 0.001 | 0.225 | 21.882 |
| ZA16_84_43 | 0.650 | 0.055 | 0.047 | 0.002 | 0.449 | 21.231 |
| ZA16_84_44 | 1.340 | 0.300 | 0.056 | 0.005 | 0.913 | 17.762 |
| ZA16_84_45 | 0.400 | 0.022 | 0.047 | 0.002 | 0.274 | 21.459 |
| ZA16_84_46 | 0.356 | 0.015 | 0.047 | 0.001 | 0.368 | 21.277 |
| ZA16_84_47 | 0.398 | 0.026 | 0.047 | 0.002 | 0.230 | 21.413 |
| ZA16_84_48 | 0.569 | 0.055 | 0.049 | 0.002 | 0.550 | 20.576 |
| ZA16_84_49 | 0.336 | 0.014 | 0.046 | 0.002 | 0.502 | 21.978 |
| ZA16_84_50 | 0.338 | 0.014 | 0.046 | 0.002 | 0.334 | 21.786 |
| ZA16_84_51 | 0.346 | 0.018 | 0.046 | 0.002 | 0.784 | 21.739 |
| ZA16_84_53 | 0.328 | 0.016 | 0.045 | 0.002 | 0.520 | 22.371 |
| ZA16_84_54 | 0.347 | 0.015 | 0.048 | 0.002 | 0.403 | 21.008 |
| ZA16_84_55 | 0.374 | 0.029 | 0.049 | 0.002 | 0.234 | 20.450 |
| ZA16_84_56 | 0.333 | 0.017 | 0.047 | 0.002 | 0.291 | 21.277 |
| ZA16_84_57 | 0.335 | 0.026 | 0.046 | 0.002 | 0.191 | 21.834 |
| ZA16_84_58 | 0.368 | 0.022 | 0.049 | 0.001 | 0.066 | 20.243 |
| ZA16_84_59 | 0.345 | 0.019 | 0.048 | 0.001 | 0.062 | 20.704 |
| ZA16_84_60 | 0.341 | 0.016 | 0.047 | 0.001 | 0.007 | 21.186 |
| ZA16_84_61 | 0.350 | 0.016 | 0.048 | 0.001 | 0.113 | 20.661 |
| ZA16_84_62 | 0.577 | 0.060 | 0.050 | 0.002 | 0.402 | 19.960 |
| ZA16_84_63 | 0.341 | 0.018 | 0.047 | 0.001 | 0.177 | 21.186 |
| ZA16_84_64 | 0.455 | 0.024 | 0.048 | 0.001 | 0.252 | 20.964 |
| ZA16_84_65 | 0.330 | 0.014 | 0.046 | 0.001 | 0.134 | 21.678 |
| ZA16_84_66 | 0.392 | 0.017 | 0.048 | 0.001 | 0.004 | 20.704 |
| ZA16_84_67 | 0.349 | 0.015 | 0.047 | 0.001 | 0.225 | 21.169 |
| ZA16_84_68 | 0.623 | 0.061 | 0.051 | 0.001 | 0.436 | 19.763 |
| ZA16_84_69 | 0.368 | 0.023 | 0.047 | 0.001 | 0.323 | 21.277 |
| ZA16_84_70 | 0.351 | 0.026 | 0.047 | 0.001 | 0.510 | 21.209 |
| ZA16_84_71 | 0.367 | 0.013 | 0.049 | 0.001 | 0.030 | 20.462 |
| ZA16_84_72 | 0.355 | 0.014 | 0.048 | 0.001 | 0.250 | 20.921 |
| ZA16_84_73 | 0.509 | 0.035 | 0.051 | 0.002 | 0.287 | 19.646 |
| ZA16_84_74 | 0.699 | 0.048 | 0.051 | 0.001 | 0.010 | 19.724 |
| ZA16_119_1 | 0.687 | 0.016 | 0.023 | 0.001 | 0.562 | 43.459 |
| ZA16_119_2 | 0.330 | 0.011 | 0.027 | 0.001 | 0.504 | 37.736 |
| ZA16_119_3 | 3.080 | 0.300 | 0.060 | 0.003 | 0.868 | 16.722 |
| ZA16_119_4 | 0.344 | 0.010 | 0.047 | 0.001 | 0.333 | 21.102 |
| ZA16_119_5 | 0.774 | 0.073 | 0.051 | 0.002 | 0.444 | 19.763 |
| ZA16_119_6 | 0.351 | 0.012 | 0.047 | 0.001 | 0.296 | 21.427 |
| ZA16_119_7 | 0.330 | 0.016 | 0.048 | 0.001 | 0.107 | 20.833 |

|                |       |       |       |       |       |         |
|----------------|-------|-------|-------|-------|-------|---------|
| ZA16_119_8     | 0.514 | 0.020 | 0.057 | 0.002 | 0.120 | 17.422  |
| ZA16_119_9     | 0.552 | 0.026 | 0.052 | 0.001 | 0.291 | 19.084  |
| ZA16_119_10    | 0.362 | 0.016 | 0.048 | 0.001 | 0.103 | 20.636  |
| ZA16_119_11    | 0.388 | 0.023 | 0.048 | 0.001 | 0.452 | 20.921  |
| ZA16_119_12    | 0.408 | 0.016 | 0.049 | 0.001 | 0.010 | 20.325  |
| ZA16_119_13    | 3.650 | 0.230 | 0.077 | 0.003 | 0.918 | 12.920  |
| ZA16_119_14    | 0.358 | 0.021 | 0.031 | 0.001 | 0.070 | 32.031  |
| ZA16_119_15    | 0.289 | 0.026 | 0.032 | 0.002 | 0.788 | 31.447  |
| ZA16_119_16    | 0.360 | 0.021 | 0.035 | 0.001 | 0.537 | 28.736  |
| ZA16_119_17    | 0.541 | 0.018 | 0.047 | 0.002 | 0.348 | 21.459  |
| ZA16_119_18    | 0.378 | 0.012 | 0.042 | 0.002 | 0.265 | 23.810  |
| ZA16_119_19    | 0.350 | 0.012 | 0.047 | 0.001 | 0.268 | 21.277  |
| ZA16_119_20    | 0.358 | 0.016 | 0.048 | 0.001 | 0.024 | 20.833  |
| ZA16_119_21    | 0.259 | 0.007 | 0.026 | 0.001 | 0.462 | 38.580  |
| ZA16_119_22    | 0.579 | 0.060 | 0.048 | 0.003 | 0.463 | 21.008  |
| ZA16_119_24    | 0.843 | 0.075 | 0.051 | 0.001 | 0.512 | 19.685  |
| ZA16_119_25    | 2.760 | 0.190 | 0.067 | 0.002 | 0.766 | 14.881  |
| ZA16_119_26    | 0.347 | 0.013 | 0.046 | 0.001 | 0.501 | 21.978  |
| ZA16_119_27    | 0.351 | 0.014 | 0.046 | 0.002 | 0.606 | 21.882  |
| ZA16_119_28    | 0.400 | 0.011 | 0.049 | 0.001 | 0.142 | 20.547  |
| ZA16_119_29    | 0.358 | 0.017 | 0.048 | 0.002 | 0.637 | 21.008  |
| ZA16_119_30    | 0.467 | 0.022 | 0.045 | 0.001 | 0.424 | 22.075  |
| ZA16_119_31    | 0.938 | 0.036 | 0.046 | 0.002 | 0.267 | 21.978  |
| ZA16_119_32    | 0.372 | 0.019 | 0.011 | 0.000 | 0.010 | 93.371  |
| ZA16_119_33    | 0.631 | 0.034 | 0.016 | 0.001 | 0.551 | 61.728  |
| ZA16_119_34    | 0.836 | 0.050 | 0.019 | 0.002 | 0.742 | 53.476  |
| ZA16_119_35    | 0.324 | 0.016 | 0.007 | 0.001 | 0.673 | 152.905 |
| ZA16_119_36    | 0.247 | 0.014 | 0.012 | 0.001 | 0.607 | 81.833  |
| ZA16_119_37    | 0.371 | 0.017 | 0.050 | 0.002 | 0.161 | 20.000  |
| ZA16_119_39    | 0.360 | 0.012 | 0.049 | 0.001 | 0.363 | 20.619  |
| ZA16_119_40    | 0.264 | 0.007 | 0.021 | 0.001 | 0.701 | 47.461  |
| ZA16_119_41    | 0.375 | 0.016 | 0.014 | 0.001 | 0.817 | 69.061  |
| ZA16_119_42    | 0.648 | 0.023 | 0.045 | 0.001 | 0.361 | 22.371  |
| ZA16_119_43    | 0.386 | 0.020 | 0.047 | 0.001 | 0.674 | 21.097  |
|                |       |       |       |       |       |         |
| Z_Plesovice_1  | 0.398 | 0.014 | 0.055 | 0.001 | 0.410 | 18.215  |
| Z_Plesovice_2  | 0.411 | 0.013 | 0.055 | 0.001 | 0.257 | 18.315  |
| Z_Plesovice_3  | 0.392 | 0.009 | 0.054 | 0.001 | 0.401 | 18.460  |
| Z_Plesovice_4  | 0.399 | 0.009 | 0.053 | 0.001 | 0.293 | 18.847  |
| Z_Plesovice_5  | 0.410 | 0.014 | 0.057 | 0.002 | 0.584 | 17.699  |
| Z_Plesovice_6  | 0.396 | 0.009 | 0.053 | 0.001 | 0.412 | 18.720  |
| Z_Plesovice_7  | 0.409 | 0.011 | 0.056 | 0.002 | 0.357 | 17.953  |
| Z_Plesovice_8  | 0.405 | 0.013 | 0.057 | 0.001 | 0.323 | 17.575  |
| Z_Plesovice_9  | 0.399 | 0.010 | 0.054 | 0.001 | 0.371 | 18.352  |
| Z_Plesovice_10 | 0.404 | 0.011 | 0.056 | 0.002 | 0.261 | 17.825  |
| Z_Plesovice_11 | 0.406 | 0.013 | 0.056 | 0.001 | 0.418 | 17.953  |
| Z_Plesovice_12 | 0.392 | 0.010 | 0.054 | 0.001 | 0.387 | 18.362  |
| Z_Plesovice_13 | 0.412 | 0.011 | 0.056 | 0.002 | 0.518 | 17.825  |
| Z_Plesovice_14 | 0.400 | 0.012 | 0.055 | 0.001 | 0.296 | 18.282  |
| Z_Plesovice_15 | 0.408 | 0.016 | 0.055 | 0.001 | 0.571 | 18.051  |

|                |       |       |       |       |       |        |
|----------------|-------|-------|-------|-------|-------|--------|
| Z_Plesovice_16 | 0.404 | 0.010 | 0.056 | 0.002 | 0.410 | 17.762 |
| Z_Plesovice_17 | 0.412 | 0.014 | 0.055 | 0.001 | 0.330 | 18.116 |
| Z_Plesovice_18 | 0.401 | 0.009 | 0.054 | 0.001 | 0.454 | 18.522 |
| Z_Plesovice_19 | 0.407 | 0.012 | 0.056 | 0.001 | 0.434 | 17.762 |
| Z_Plesovice_20 | 0.412 | 0.012 | 0.055 | 0.001 | 0.476 | 18.083 |
| Z_Temora2_1    | 0.509 | 0.026 | 0.067 | 0.002 | 0.075 | 14.881 |
| Z_Temora2_2    | 0.488 | 0.030 | 0.066 | 0.002 | 0.010 | 15.198 |
| Z_Temora2_3    | 0.507 | 0.025 | 0.067 | 0.002 | 0.224 | 15.038 |
| Z_Temora2_4    | 0.499 | 0.025 | 0.065 | 0.001 | 0.102 | 15.337 |
| Z_Temora2_5    | 0.507 | 0.026 | 0.067 | 0.001 | 0.169 | 14.903 |
| Z_Temora2_6    | 0.515 | 0.027 | 0.068 | 0.002 | 0.127 | 14.663 |
| Z_Temora2_7    | 0.521 | 0.021 | 0.068 | 0.001 | 0.095 | 14.620 |
| Z_Temora2_9    | 0.511 | 0.018 | 0.066 | 0.001 | 0.157 | 15.221 |
| Z_Temora2_10   | 0.512 | 0.020 | 0.068 | 0.001 | 0.281 | 14.620 |
| Z_Temora2_11   | 0.518 | 0.023 | 0.067 | 0.001 | 0.259 | 14.948 |
| Z_Temora2_12   | 0.503 | 0.028 | 0.068 | 0.001 | 0.158 | 14.641 |
| Z_Temora2_13   | 0.493 | 0.023 | 0.065 | 0.002 | 0.119 | 15.361 |
| Z_Temora2_14   | 0.488 | 0.028 | 0.067 | 0.002 | 0.260 | 14.925 |
| Z_Temora2_15   | 0.500 | 0.029 | 0.066 | 0.001 | 0.010 | 15.106 |
| Z_Temora2_16   | 0.506 | 0.032 | 0.068 | 0.002 | 0.134 | 14.815 |
| Z_Temora2_17   | 0.510 | 0.025 | 0.065 | 0.001 | 0.348 | 15.337 |
| Z_Temora2_18   | 0.513 | 0.022 | 0.068 | 0.002 | 0.090 | 14.706 |
| Z_Temora2_20   | 0.516 | 0.026 | 0.065 | 0.002 | 0.010 | 15.385 |





| Error 2σ | <sup>207</sup> Pb/ <sup>206</sup> Pb | Error 2σ | Correlation_38_ | FinalAge <sup>206</sup> Pb/ <sup>23</sup> | Error 2σ | FinalAge <sup>207</sup> Pb |
|----------|--------------------------------------|----------|-----------------|-------------------------------------------|----------|----------------------------|
| 0.222    | 0.056                                | 0.003    | 0.297           | 525.304                                   | 9.900    | 515.837                    |
| 0.209    | 0.056                                | 0.003    | 0.335           | 524.116                                   | 9.282    | 514.614                    |
| 0.269    | 0.058                                | 0.003    | 0.119           | 519.954                                   | 11.761   | 523.142                    |
| 0.271    | 0.055                                | 0.003    | 0.217           | 518.765                                   | 11.762   | 504.780                    |
| 0.253    | 0.057                                | 0.003    | 0.454           | 521.738                                   | 11.140   | 510.937                    |
| 0.243    | 0.057                                | 0.003    | 0.481           | 518.170                                   | 10.524   | 520.104                    |
| 0.227    | 0.057                                | 0.003    | 0.193           | 519.360                                   | 9.904    | 515.225                    |
| 0.233    | 0.058                                | 0.003    | 0.645           | 512.814                                   | 9.909    | 515.225                    |
| 0.228    | 0.058                                | 0.003    | 0.469           | 518.765                                   | 9.905    | 520.712                    |
| 0.259    | 0.057                                | 0.003    | 0.196           | 516.385                                   | 11.145   | 523.142                    |
| 0.215    | 0.059                                | 0.003    | 0.458           | 517.575                                   | 9.287    | 527.982                    |
| 0.233    | 0.057                                | 0.003    | 0.424           | 528.868                                   | 10.516   | 529.189                    |
| 0.280    | 0.058                                | 0.003    | 0.464           | 535.398                                   | 12.983   | 544.746                    |
| 0.234    | 0.057                                | 0.003    | 0.318           | 527.087                                   | 10.517   | 521.928                    |
| 0.223    | 0.058                                | 0.003    | 0.285           | 524.116                                   | 9.901    | 518.887                    |
| 0.231    | 0.059                                | 0.004    | 0.404           | 530.056                                   | 10.515   | 545.340                    |
| 0.236    | 0.057                                | 0.003    | 0.111           | 539.549                                   | 11.125   | 529.189                    |
| 0.256    | 0.057                                | 0.003    | 0.208           | 532.431                                   | 11.749   | 526.170                    |
| 0.298    | 0.057                                | 0.004    | 0.159           | 519.360                                   | 12.999   | 527.982                    |
| 0.230    | 0.056                                | 0.003    | 0.366           | 531.837                                   | 10.513   | 523.748                    |
| 0.625    | 0.114                                | 0.007    | 0.154           | 308.379                                   | 9.440    | 579.189                    |
| 0.417    | 0.051                                | 0.002    | 0.322           | 299.093                                   | 5.920    | 300.953                    |
| 0.483    | 0.052                                | 0.002    | 0.248           | 286.835                                   | 6.304    | 291.092                    |
| 0.440    | 0.060                                | 0.004    | 0.250           | 300.385                                   | 6.297    | 338.015                    |
| 0.485    | 0.075                                | 0.006    | -0.029          | 299.770                                   | 6.927    | 400.813                    |
| 4.217    | 0.069                                | 0.003    | -0.196          | 98.518                                    | 6.397    | 140.675                    |
| 0.442    | 0.051                                | 0.003    | 0.268           | 296.754                                   | 6.173    | 292.615                    |
| 0.523    | 0.048                                | 0.004    | 0.516           | 301.616                                   | 7.556    | 281.133                    |
| 0.485    | 0.051                                | 0.002    | 0.065           | 299.770                                   | 6.927    | 297.172                    |
| 0.455    | 0.050                                | 0.002    | 0.339           | 295.461                                   | 6.300    | 287.273                    |
| 0.440    | 0.053                                | 0.003    | 0.386           | 300.385                                   | 6.297    | 306.975                    |
| 0.618    | 0.055                                | 0.004    | 0.317           | 299.770                                   | 8.817    | 309.224                    |
| 0.598    | 0.072                                | 0.005    | -0.514          | 315.136                                   | 9.435    | 421.135                    |
| 0.670    | 0.054                                | 0.004    | 0.297           | 288.068                                   | 8.825    | 298.686                    |
| 0.519    | 0.060                                | 0.002    | 0.175           | 302.846                                   | 7.555    | 335.100                    |
| 0.732    | 0.091                                | 0.004    | 0.201           | 303.461                                   | 10.703   | 492.976                    |
| 5.443    | 0.091                                | 0.010    | 0.925           | 106.132                                   | 9.590    | 188.505                    |
| 0.679    | 0.074                                | 0.004    | 0.507           | 286.218                                   | 8.826    | 388.422                    |
| 0.664    | 0.093                                | 0.007    | 0.423           | 318.204                                   | 10.691   | 517.668                    |
| 0.781    | 0.094                                | 0.007    | -0.179          | 318.204                                   | 12.577   | 513.390                    |
| 0.483    | 0.058                                | 0.003    | 0.051           | 300.385                                   | 6.927    | 327.038                    |
| 0.425    | 0.052                                | 0.002    | 0.532           | 304.015                                   | 6.233    | 303.216                    |
| 0.460    | 0.095                                | 0.007    | -0.447          | 307.765                                   | 6.923    | 509.709                    |
| 0.428    | 0.060                                | 0.002    | 0.388           | 302.723                                   | 6.233    | 343.098                    |
| 0.453    | 0.069                                | 0.003    | 0.562           | 296.077                                   | 6.300    | 373.772                    |
| 0.468    | 0.283                                | 0.013    | -0.232          | 408.382                                   | 12.489   | 1274.931                   |
| 2.904    | 0.076                                | 0.004    | 0.746           | 97.185                                    | 4.287    | 152.452                    |
| 1.280    | 0.062                                | 0.004    | 0.426           | 255.931                                   | 13.271   | 300.198                    |

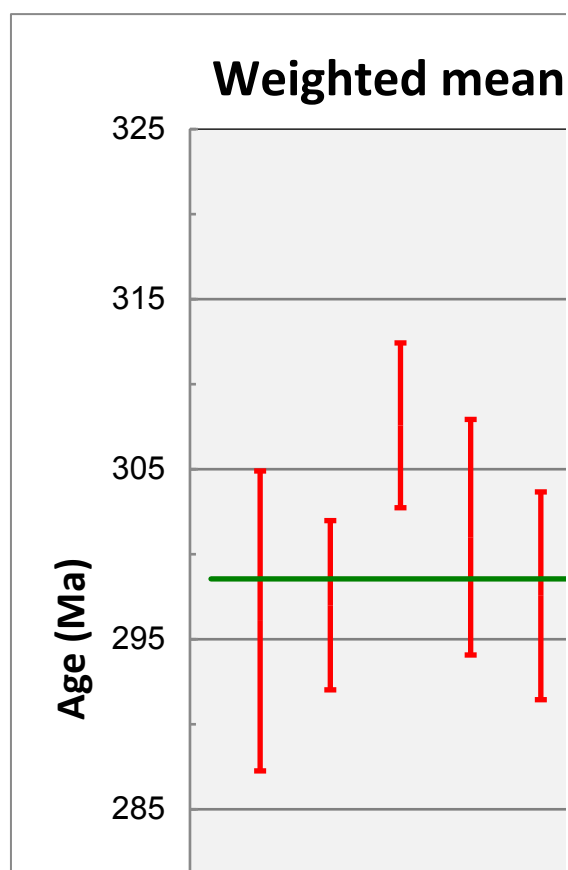
|       |       |       |        |         |        |          |
|-------|-------|-------|--------|---------|--------|----------|
| 0.750 | 0.051 | 0.003 | 0.182  | 299.770 | 10.706 | 293.376  |
| 0.861 | 0.099 | 0.010 | -0.006 | 303.461 | 12.592 | 514.002  |
| 2.013 | 0.062 | 0.002 | 0.574  | 204.927 | 13.323 | 245.887  |
| 0.400 | 0.051 | 0.002 | 0.514  | 298.601 | 5.668  | 288.496  |
| 0.548 | 0.055 | 0.002 | 0.171  | 258.967 | 5.812  | 274.181  |
| 0.726 | 0.065 | 0.004 | 0.336  | 276.962 | 8.832  | 336.559  |
| 0.477 | 0.050 | 0.002 | 0.335  | 302.231 | 6.926  | 294.136  |
| 0.524 | 0.053 | 0.002 | 0.471  | 288.684 | 6.933  | 299.442  |
| 0.729 | 0.071 | 0.005 | 0.263  | 304.076 | 10.702 | 394.637  |
| 1.025 | 0.081 | 0.005 | 0.044  | 304.691 | 15.109 | 431.810  |
| 0.670 | 0.076 | 0.004 | 0.319  | 288.068 | 8.825  | 397.387  |
| 0.902 | 0.095 | 0.007 | 0.144  | 296.693 | 12.598 | 508.479  |
| 1.420 | 0.164 | 0.022 | -0.685 | 353.085 | 28.222 | 863.229  |
| 0.829 | 0.064 | 0.003 | 0.277  | 293.614 | 11.341 | 341.648  |
| 0.543 | 0.055 | 0.002 | 0.385  | 296.077 | 7.559  | 309.224  |
| 0.688 | 0.062 | 0.004 | 0.246  | 294.230 | 9.451  | 340.197  |
| 1.016 | 0.087 | 0.007 | 0.008  | 305.921 | 15.107 | 457.368  |
| 0.773 | 0.054 | 0.002 | 0.428  | 286.835 | 10.086 | 294.136  |
| 0.712 | 0.055 | 0.002 | 0.505  | 289.301 | 9.454  | 295.655  |
| 0.898 | 0.055 | 0.003 | 0.288  | 289.917 | 11.975 | 301.708  |
| 0.901 | 0.054 | 0.003 | 0.244  | 281.900 | 11.352 | 288.038  |
| 0.794 | 0.053 | 0.002 | 0.479  | 299.770 | 11.336 | 302.462  |
| 0.753 | 0.054 | 0.004 | 0.306  | 307.765 | 11.329 | 322.614  |
| 1.086 | 0.053 | 0.003 | 0.150  | 296.077 | 15.119 | 291.854  |
| 1.001 | 0.051 | 0.005 | 0.363  | 288.684 | 13.237 | 293.376  |
| 0.451 | 0.055 | 0.003 | 0.287  | 310.837 | 6.921  | 318.170  |
| 0.429 | 0.052 | 0.003 | 0.332  | 304.076 | 6.296  | 300.953  |
| 0.628 | 0.053 | 0.003 | 0.460  | 297.308 | 8.818  | 297.929  |
| 0.470 | 0.053 | 0.003 | 0.336  | 304.691 | 6.925  | 304.721  |
| 0.876 | 0.088 | 0.009 | 0.066  | 315.136 | 13.838 | 462.532  |
| 0.494 | 0.052 | 0.003 | 0.265  | 297.308 | 6.929  | 297.929  |
| 0.483 | 0.069 | 0.004 | 0.203  | 300.385 | 6.927  | 380.775  |
| 0.432 | 0.051 | 0.002 | 0.264  | 290.718 | 5.798  | 289.566  |
| 0.472 | 0.058 | 0.003 | 0.346  | 304.076 | 6.925  | 335.829  |
| 0.435 | 0.053 | 0.002 | 0.205  | 297.554 | 6.110  | 303.969  |
| 0.547 | 0.092 | 0.009 | -0.151 | 318.204 | 8.804  | 491.726  |
| 0.634 | 0.056 | 0.003 | -0.045 | 296.077 | 8.819  | 318.170  |
| 0.355 | 0.053 | 0.003 | -0.287 | 297.000 | 4.976  | 305.473  |
| 0.322 | 0.054 | 0.002 | 0.342  | 307.580 | 4.846  | 317.428  |
| 0.481 | 0.054 | 0.002 | 0.303  | 301.001 | 6.927  | 308.475  |
| 0.579 | 0.075 | 0.005 | 0.140  | 320.045 | 9.432  | 417.776  |
| 0.428 | 0.100 | 0.007 | 0.364  | 318.818 | 6.917  | 538.193  |
| 1.757 | 0.220 | 0.008 | 0.785  | 146.651 | 5.927  | 530.996  |
| 1.125 | 0.090 | 0.003 | 0.495  | 168.606 | 5.026  | 289.566  |
| 0.839 | 0.362 | 0.017 | -0.476 | 374.409 | 18.783 | 1427.727 |
| 0.423 | 0.055 | 0.002 | 0.395  | 298.478 | 5.983  | 300.198  |
| 0.586 | 0.107 | 0.009 | -0.355 | 318.204 | 9.433  | 582.055  |
| 0.367 | 0.056 | 0.002 | 0.160  | 294.045 | 5.040  | 305.473  |
| 0.608 | 0.050 | 0.003 | 0.419  | 302.231 | 8.815  | 289.566  |

|        |       |       |        |         |        |          |
|--------|-------|-------|--------|---------|--------|----------|
| 0.486  | 0.065 | 0.003 | 0.298  | 359.794 | 10.029 | 421.135  |
| 0.364  | 0.076 | 0.004 | 0.075  | 329.239 | 6.283  | 446.306  |
| 0.417  | 0.054 | 0.003 | 0.345  | 305.060 | 6.169  | 313.707  |
| 0.481  | 0.059 | 0.004 | -0.086 | 301.001 | 6.927  | 332.907  |
| 0.454  | 0.061 | 0.003 | 0.424  | 309.608 | 6.922  | 347.434  |
| 0.451  | 0.339 | 0.011 | -0.569 | 480.585 | 16.765 | 1560.509 |
| 1.016  | 0.084 | 0.006 | 0.342  | 198.179 | 6.284  | 310.720  |
| 1.879  | 0.065 | 0.003 | -0.092 | 201.804 | 12.057 | 257.772  |
| 1.156  | 0.074 | 0.003 | 0.299  | 220.520 | 8.871  | 312.215  |
| 0.875  | 0.084 | 0.003 | 0.536  | 293.614 | 11.971 | 439.084  |
| 0.850  | 0.068 | 0.003 | 0.583  | 265.218 | 9.472  | 325.565  |
| 0.543  | 0.054 | 0.002 | 0.507  | 296.077 | 7.559  | 304.721  |
| 0.564  | 0.054 | 0.003 | 0.444  | 302.231 | 8.185  | 310.720  |
| 1.131  | 0.072 | 0.003 | 0.542  | 164.962 | 4.837  | 234.022  |
| 1.148  | 0.091 | 0.009 | -0.060 | 299.770 | 16.374 | 463.819  |
| 0.426  | 0.122 | 0.009 | -0.271 | 319.431 | 6.917  | 620.800  |
| 0.487  | 0.296 | 0.015 | -0.321 | 419.264 | 13.726 | 1344.793 |
| 0.580  | 0.055 | 0.002 | 0.308  | 286.835 | 7.565  | 302.462  |
| 0.766  | 0.057 | 0.002 | 0.100  | 288.068 | 10.086 | 305.473  |
| 0.329  | 0.060 | 0.002 | 0.452  | 306.351 | 4.910  | 341.648  |
| 0.706  | 0.055 | 0.002 | 0.177  | 299.770 | 10.076 | 310.720  |
| 0.634  | 0.077 | 0.004 | 0.226  | 285.601 | 8.196  | 389.115  |
| 0.725  | 0.152 | 0.007 | 0.437  | 286.835 | 9.456  | 671.835  |
| 2.964  | 0.253 | 0.017 | 0.523  | 68.674  | 2.180  | 321.135  |
| 3.810  | 0.296 | 0.019 | 0.780  | 103.595 | 6.395  | 496.719  |
| 5.147  | 0.326 | 0.024 | 0.801  | 119.435 | 11.496 | 616.936  |
| 12.391 | 0.359 | 0.022 | 0.830  | 42.022  | 3.405  | 284.975  |
| 4.018  | 0.149 | 0.006 | 0.326  | 78.298  | 3.844  | 224.136  |
| 0.760  | 0.055 | 0.002 | -0.065 | 314.522 | 11.952 | 320.394  |
| 0.425  | 0.055 | 0.002 | 0.165  | 305.306 | 6.295  | 312.215  |
| 1.892  | 0.092 | 0.003 | 0.696  | 134.415 | 5.359  | 237.564  |
| 4.102  | 0.188 | 0.007 | 0.762  | 92.675  | 5.504  | 323.353  |
| 0.500  | 0.106 | 0.004 | 0.190  | 281.900 | 6.306  | 507.247  |
| 0.490  | 0.060 | 0.002 | -0.379 | 298.539 | 6.928  | 331.443  |
| 0.464  | 0.053 | 0.002 | 0.541  | 344.535 | 8.786  | 340.197  |
| 0.436  | 0.053 | 0.002 | 0.412  | 342.701 | 8.160  | 349.595  |
| 0.317  | 0.052 | 0.001 | 0.296  | 340.072 | 5.838  | 335.465  |
| 0.284  | 0.053 | 0.001 | 0.376  | 333.281 | 5.025  | 340.850  |
| 0.470  | 0.053 | 0.002 | 0.231  | 354.305 | 9.406  | 348.875  |
| 0.322  | 0.053 | 0.001 | 0.389  | 335.484 | 5.778  | 338.525  |
| 0.483  | 0.053 | 0.002 | 0.666  | 349.422 | 9.410  | 348.155  |
| 0.432  | 0.053 | 0.002 | 0.489  | 356.745 | 8.778  | 345.268  |
| 0.320  | 0.053 | 0.001 | 0.372  | 342.029 | 5.963  | 340.923  |
| 0.477  | 0.053 | 0.002 | 0.643  | 351.864 | 9.408  | 344.545  |
| 0.419  | 0.054 | 0.002 | 0.384  | 349.422 | 8.155  | 345.991  |
| 0.283  | 0.052 | 0.001 | 0.248  | 341.846 | 5.273  | 335.829  |
| 0.477  | 0.053 | 0.001 | 0.550  | 351.864 | 9.408  | 350.314  |
| 0.334  | 0.053 | 0.002 | 0.481  | 343.313 | 6.276  | 341.648  |
| 0.358  | 0.054 | 0.002 | 0.223  | 347.590 | 6.902  | 347.434  |

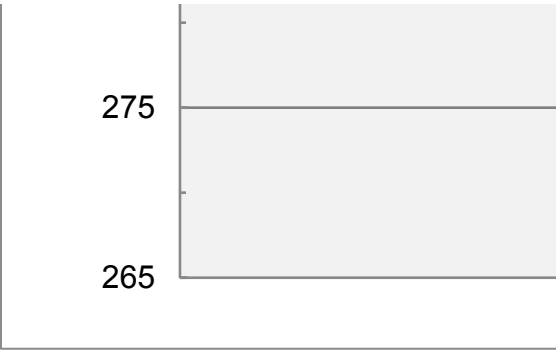
|       |       |       |       |         |        |         |
|-------|-------|-------|-------|---------|--------|---------|
| 0.473 | 0.053 | 0.001 | 0.606 | 353.085 | 9.407  | 344.256 |
| 0.459 | 0.054 | 0.002 | 0.396 | 346.368 | 8.785  | 350.314 |
| 0.257 | 0.054 | 0.001 | 0.183 | 338.972 | 4.709  | 342.228 |
| 0.410 | 0.052 | 0.002 | 0.369 | 353.085 | 8.153  | 346.712 |
| 0.425 | 0.054 | 0.002 | 0.456 | 346.979 | 8.157  | 350.314 |
|       |       |       |       |         |        |         |
| 0.421 | 0.055 | 0.003 | 0.369 | 419.264 | 11.854 | 417.776 |
| 0.370 | 0.054 | 0.004 | 0.515 | 410.802 | 9.989  | 403.547 |
| 0.362 | 0.055 | 0.003 | 0.224 | 415.035 | 9.986  | 416.430 |
| 0.329 | 0.056 | 0.003 | 0.324 | 407.172 | 8.743  | 411.025 |
| 0.267 | 0.055 | 0.003 | 0.272 | 418.660 | 7.487  | 416.430 |
| 0.344 | 0.055 | 0.003 | 0.374 | 425.302 | 9.978  | 421.806 |
| 0.299 | 0.056 | 0.002 | 0.419 | 426.509 | 8.730  | 425.819 |
| 0.278 | 0.056 | 0.002 | 0.308 | 410.197 | 7.492  | 419.121 |
| 0.278 | 0.054 | 0.002 | 0.207 | 426.509 | 8.106  | 419.793 |
| 0.290 | 0.056 | 0.002 | 0.158 | 417.452 | 8.112  | 423.814 |
| 0.279 | 0.053 | 0.003 | 0.182 | 425.906 | 8.107  | 413.731 |
| 0.354 | 0.056 | 0.003 | 0.358 | 406.567 | 9.368  | 406.953 |
| 0.356 | 0.054 | 0.003 | 0.082 | 418.056 | 9.983  | 403.547 |
| 0.297 | 0.055 | 0.004 | 0.358 | 413.221 | 8.115  | 411.702 |
| 0.329 | 0.055 | 0.003 | 0.196 | 421.076 | 9.357  | 415.756 |
| 0.282 | 0.057 | 0.003 | 0.090 | 407.172 | 7.494  | 418.449 |
| 0.324 | 0.056 | 0.003 | 0.370 | 424.095 | 9.355  | 420.464 |
| 0.355 | 0.056 | 0.003 | 0.429 | 405.962 | 9.368  | 422.476 |



| Error 2 $\sigma$ | FinalAge <sup>207</sup> Pb | Error 2 $\sigma$ |
|------------------|----------------------------|------------------|
| 23.376           | 452.368                    | 21.003           |
| 24.171           | 464.219                    | 23.087           |
| 25.614           | 529.762                    | 27.401           |
| 28.217           | 428.402                    | 23.972           |
| 21.875           | 499.252                    | 23.566           |
| 24.878           | 491.533                    | 25.870           |
| 23.384           | 491.533                    | 25.008           |
| 24.163           | 537.299                    | 30.465           |
| 23.315           | 522.189                    | 26.200           |
| 26.390           | 499.252                    | 25.312           |
| 23.999           | 578.128                    | 30.223           |
| 24.757           | 503.098                    | 27.218           |
| 26.086           | 544.801                    | 27.986           |
| 22.524           | 503.098                    | 23.706           |
| 24.894           | 529.762                    | 26.488           |
| 30.680           | 563.402                    | 35.392           |
| 28.626           | 499.252                    | 26.185           |
| 30.997           | 487.660                    | 29.140           |
| 34.838           | 503.098                    | 33.364           |
| 27.157           | 456.328                    | 23.589           |
|                  |                            |                  |
| 36.152           | 1859.376                   | 106.297          |
| 12.213           | 258.809                    | 10.574           |
| 11.398           | 302.904                    | 12.139           |
| 19.682           | 603.575                    | 38.226           |
| 28.156           | 1068.502                   | 82.631           |
| 8.993            | 904.708                    | 39.221           |
| 13.141           | 249.844                    | 12.687           |
| 17.626           | 94.333                     | 6.893            |
| 12.236           | 227.214                    | 10.756           |
| 12.299           | 190.338                    | 9.155            |
| 15.653           | 311.581                    | 16.586           |
| 16.504           | 404.072                    | 25.808           |
| 36.050           | 988.765                    | 71.312           |
| 18.340           | 379.369                    | 25.198           |
| 13.713           | 585.440                    | 17.711           |
| 26.818           | 1454.950                   | 55.715           |
| 9.240            | 1446.603                   | 158.967          |
| 16.670           | 1044.192                   | 50.730           |
| 34.252           | 1496.011                   | 105.714          |
| 44.473           | 1502.075                   | 112.215          |
| 18.073           | 533.535                    | 27.549           |
| 10.456           | 298.548                    | 12.558           |
| 40.652           | 1518.127                   | 106.028          |
| 8.535            | 607.177                    | 18.185           |
| 15.119           | 895.748                    | 44.202           |
| 76.191           | 3379.560                   | 155.245          |
| 5.646            | 1097.702                   | 59.140           |
| 18.326           | 670.656                    | 46.588           |

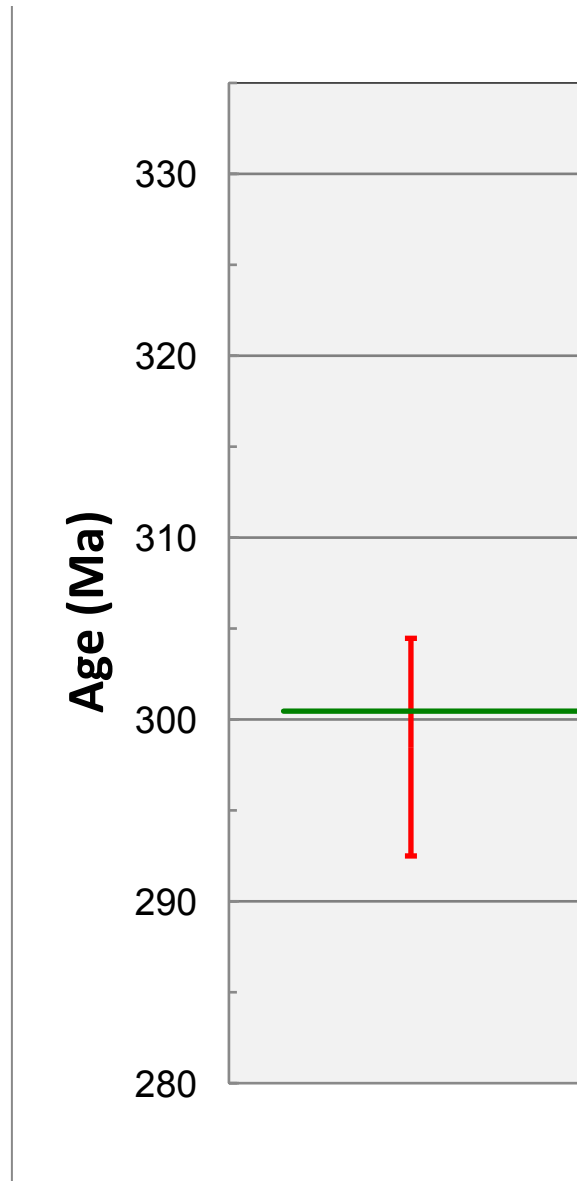


|         |          |         |
|---------|----------|---------|
| 18.391  | 240.830  | 14.639  |
| 61.618  | 1605.366 | 162.158 |
| 12.564  | 667.195  | 25.910  |
| 7.375   | 222.650  | 7.040   |
| 8.845   | 416.283  | 14.355  |
| 15.415  | 787.231  | 42.130  |
| 11.380  | 204.264  | 7.731   |
| 10.476  | 337.336  | 12.682  |
| 25.755  | 951.645  | 61.830  |
| 34.219  | 1223.869 | 72.436  |
| 21.570  | 1081.843 | 50.152  |
| 43.025  | 1535.984 | 106.263 |
| 193.260 | 2497.323 | 335.007 |
| 18.791  | 725.019  | 38.820  |
| 13.029  | 404.072  | 16.959  |
| 22.224  | 677.554  | 45.825  |
| 44.210  | 1367.125 | 114.319 |
| 12.256  | 366.874  | 14.974  |
| 12.246  | 395.880  | 17.401  |
| 15.696  | 391.768  | 17.971  |
| 14.051  | 358.489  | 16.689  |
| 13.075  | 333.072  | 13.800  |
| 25.016  | 371.050  | 28.859  |
| 14.899  | 307.249  | 16.387  |
| 22.769  | 245.343  | 22.086  |
| 19.021  | 408.153  | 25.277  |
| 16.574  | 272.164  | 15.793  |
| 13.979  | 315.902  | 19.182  |
| 13.930  | 333.072  | 15.681  |
| 48.097  | 1373.727 | 147.409 |
| 15.726  | 302.904  | 16.764  |
| 20.085  | 901.727  | 48.283  |
| 12.285  | 254.333  | 11.899  |
| 14.564  | 537.299  | 27.696  |
| 13.065  | 315.902  | 13.787  |
| 48.147  | 1457.030 | 144.907 |
| 19.886  | 456.328  | 25.216  |
| 22.628  | 307.249  | 19.313  |
| 11.244  | 387.646  | 14.252  |
| 12.165  | 358.489  | 16.022  |
| 28.727  | 1073.852 | 74.256  |
| 36.957  | 1622.222 | 115.293 |
|         |          |         |
| 12.367  | 2982.154 | 108.343 |
| 9.652   | 1433.994 | 46.002  |
| 139.064 | 3758.268 | 176.493 |
| 8.727   | 395.880  | 11.601  |
| 54.897  | 1750.645 | 143.844 |
| 10.444  | 440.430  | 15.024  |
| 14.040  | 208.880  | 11.628  |



|        |          |         |
|--------|----------|---------|
| 16.387 | 784.017  | 30.016  |
| 21.022 | 1102.953 | 50.594  |
| 13.865 | 375.215  | 18.726  |
| 19.734 | 578.128  | 34.122  |
| 13.625 | 642.756  | 29.455  |
| 98.333 | 3658.268 | 118.705 |
| 18.227 | 1283.261 | 87.495  |
| 23.191 | 761.336  | 37.713  |
| 18.213 | 1027.771 | 46.145  |
| 14.609 | 1283.261 | 52.190  |
| 10.335 | 853.240  | 36.658  |
| 10.448 | 375.215  | 13.871  |
| 13.887 | 350.061  | 18.321  |
| 6.681  | 985.941  | 38.342  |
| 48.064 | 1452.868 | 144.809 |
| 55.231 | 1979.834 | 153.046 |
| 92.576 | 3449.416 | 174.801 |
| 11.331 | 420.333  | 13.707  |
| 12.184 | 483.777  | 19.590  |
| 9.395  | 603.575  | 19.113  |
| 14.755 | 404.072  | 16.959  |
| 18.331 | 1108.185 | 50.701  |
| 25.785 | 2373.031 | 102.769 |
| 16.402 | 3203.637 | 215.264 |
| 26.765 | 3449.416 | 221.415 |
| 36.898 | 3598.375 | 264.911 |
| 14.073 | 3745.628 | 229.537 |
| 12.704 | 2339.070 | 100.201 |
| 14.681 | 404.072  | 15.485  |
| 10.407 | 391.768  | 12.939  |
| 6.399  | 1467.386 | 43.065  |
| 13.796 | 2722.990 | 97.146  |
| 18.004 | 1738.633 | 58.826  |
| 17.173 | 596.346  | 23.934  |

|        |         |        |
|--------|---------|--------|
| 11.967 | 311.581 | 10.070 |
| 11.058 | 337.336 | 12.048 |
| 7.798  | 276.591 | 7.475  |
| 7.947  | 345.831 | 8.419  |
| 11.913 | 315.902 | 9.591  |
| 7.785  | 337.336 | 7.609  |
| 9.364  | 341.589 | 10.254 |
| 11.083 | 320.212 | 11.523 |
| 8.544  | 311.581 | 7.108  |
| 9.381  | 333.072 | 11.291 |
| 11.079 | 350.061 | 11.123 |
| 8.567  | 298.548 | 6.850  |
| 9.353  | 333.072 | 8.782  |
| 10.249 | 333.072 | 10.036 |
| 13.625 | 383.513 | 13.419 |



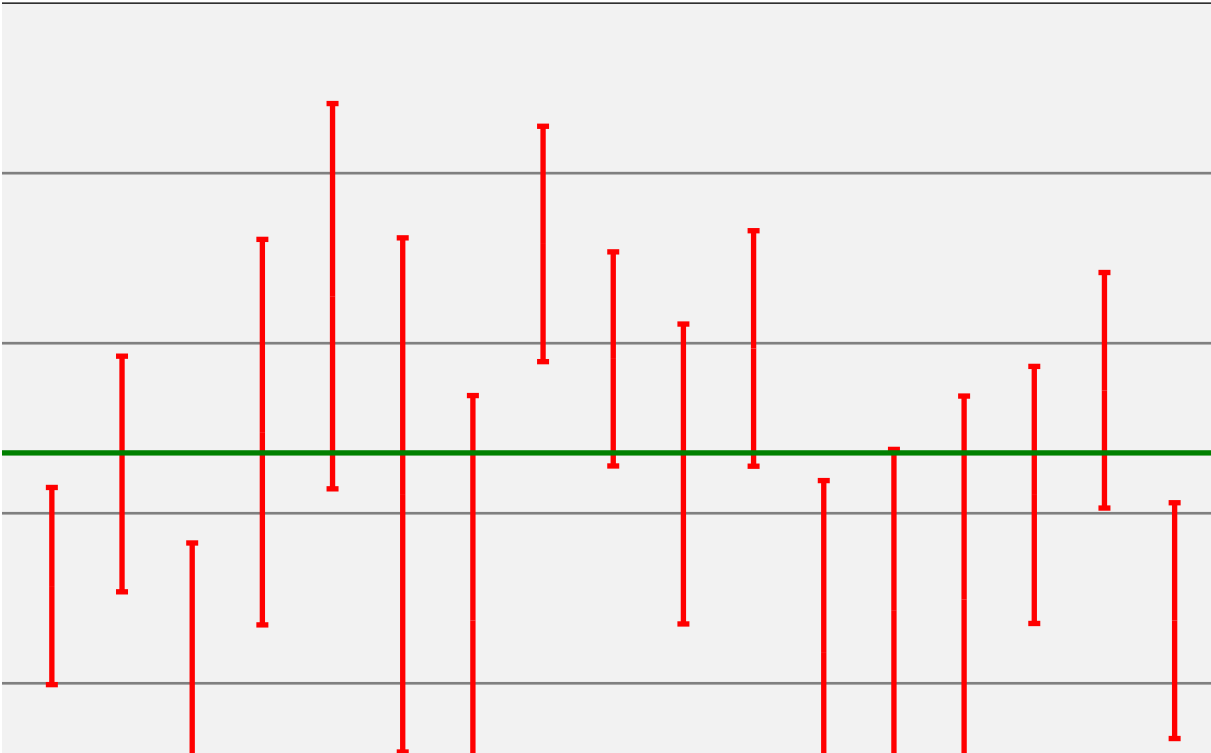


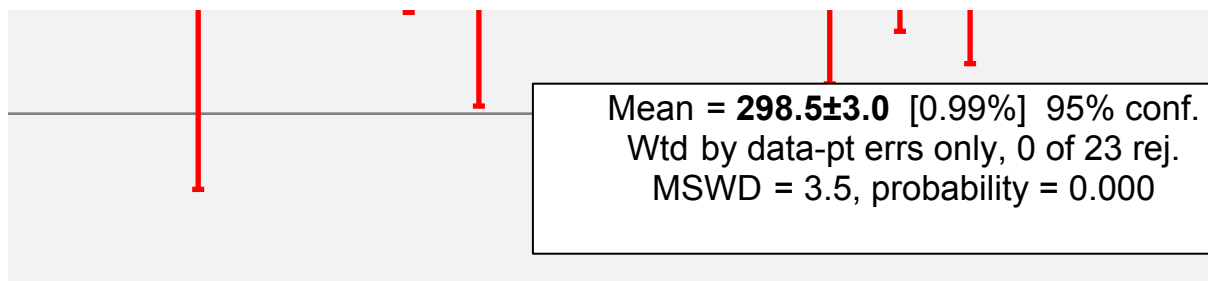
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| 8.359  | 333.072 | 8.782  |
| 11.904 | 383.513 | 14.126 |
| 7.856  | 366.874 | 8.168  |
| 10.222 | 289.801 | 8.344  |
| 10.203 | 383.513 | 12.713 |
|        |         |        |
| 21.340 | 408.153 | 23.047 |
| 24.808 | 366.874 | 25.865 |
| 20.534 | 408.153 | 20.073 |
| 20.592 | 432.421 | 22.595 |
| 21.355 | 399.981 | 19.743 |
| 22.114 | 404.072 | 22.121 |
| 17.164 | 432.421 | 17.920 |
| 14.764 | 444.419 | 15.929 |
| 16.398 | 366.874 | 14.294 |
| 18.818 | 460.278 | 19.656 |
| 23.031 | 341.589 | 19.226 |
| 18.986 | 436.431 | 21.194 |
| 23.154 | 362.687 | 20.898 |
| 23.879 | 408.153 | 28.251 |
| 26.293 | 412.223 | 25.483 |
| 20.512 | 499.252 | 24.439 |
| 18.032 | 436.431 | 21.194 |
| 21.288 | 464.219 | 23.087 |



age - zircon ZA16-84

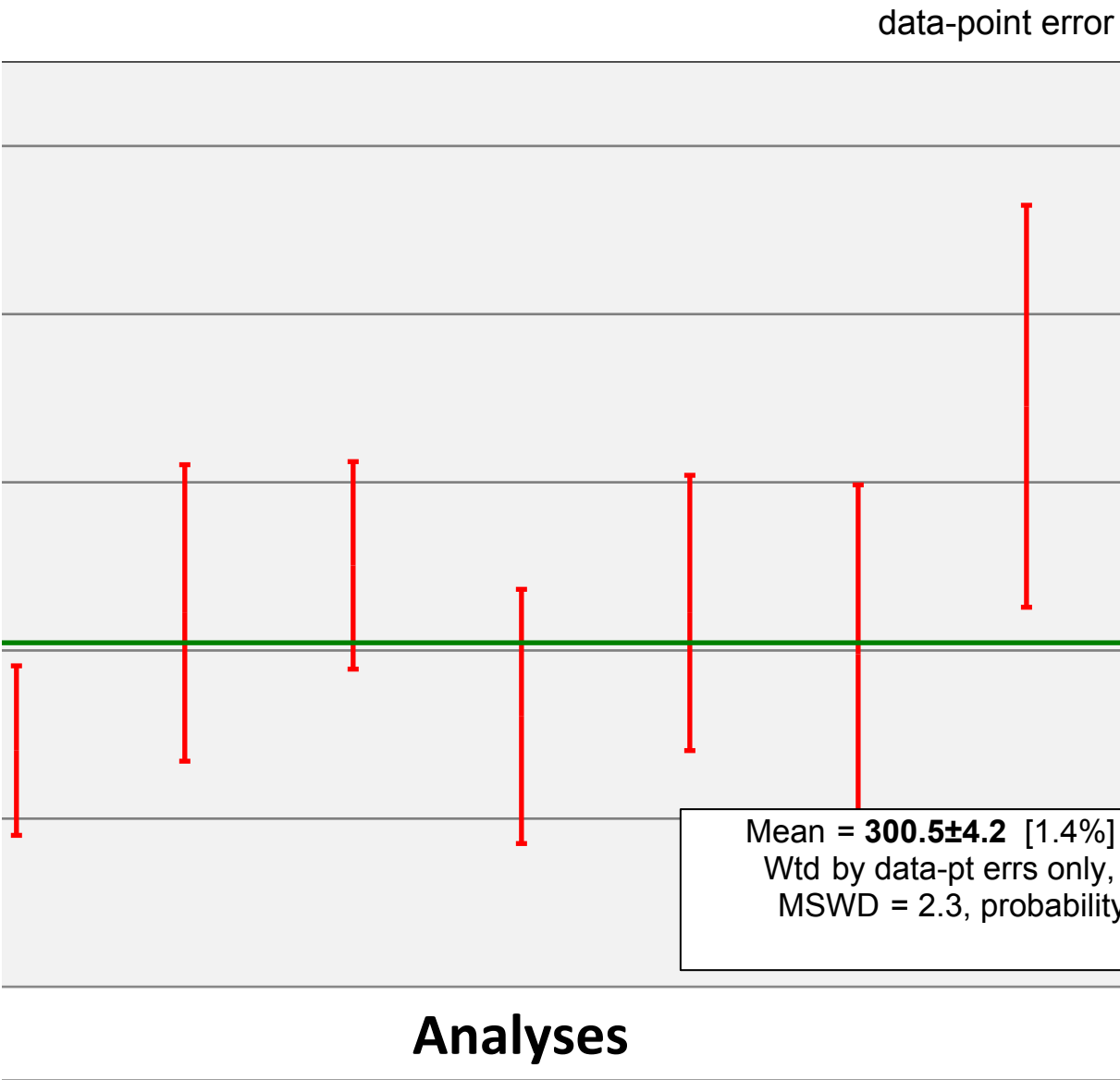
data-point error symbols





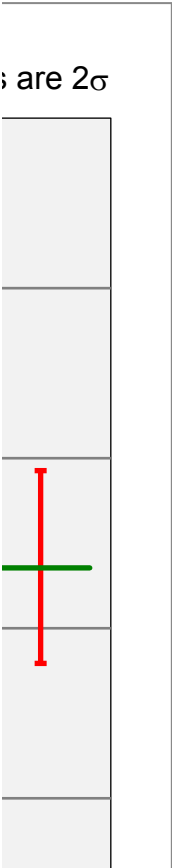
## Analyses

**Weighted mean age - zircon ZA16-119**

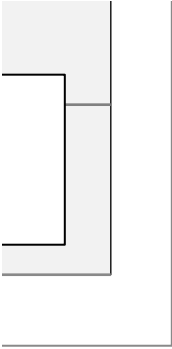




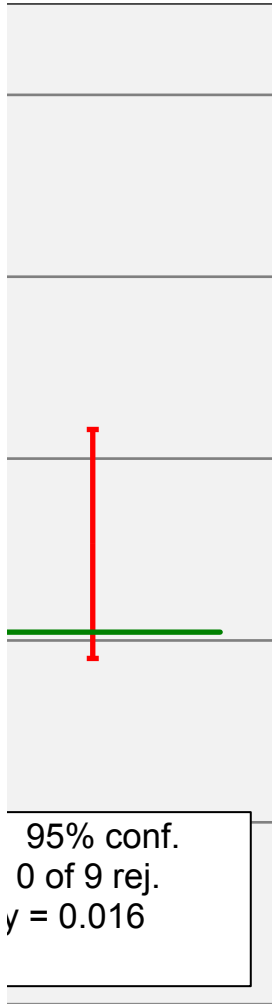








symbols are  $2\sigma$



**Pre-orogenic upper crustal softening by lower greenschist-facies metamorphic reactions  
in granites of the central Pyrenees**

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Short title: Pre-kinematic metamorphism in Pyrenees

**ABSTRACT**

Pre-kinematic greenschist-facies metamorphism is often observed in granites and basement units of mountains belts, but rarely dated and accounted for in orogenic cycle reconstructions. Studying pre-kinematic alteration is challenging because of its usual obliteration by subsequent syn-kinematic metamorphism often occurring at conditions typical of the brittle-ductile transition. It is however to be expected that pre-kinematic alteration has major implications for the rheology of the upper crust. In the 305 Ma-old Variscan basement of the Bielsa massif (located in the Axial Zone of the Pyrenees), successive fluid-rock interaction events are recorded in granites at temperatures below 350°C. Combined microstructural and petrographic analysis, low-temperature thermobarometry and *in situ* U-Th/Pb dating of anatase, titanite and monazite show extensive pre-orogenic (pre-Alpine) and pre-kinematic alteration related to feldspar sericitization and chloritization of biotite and amphibole at temperatures of 270-350°C at 230-300 Ma. This event is followed by a second fluid-rock interaction stage marked by new crystallisation of phyllosilicates at temperatures of 200-280°C and associated with the formation of mylonitic shear zones and fractures parallel to the shear planes. U-Pb anatase and monazite ages as well as the microtextural relationships of accessory minerals suggest an age for this event at 40-70 Ma, consistent with independent regional geology constraints. The Variscan basement was therefore softened at late- to post Variscan time, at least 150-200 Ma before the main Alpine shortening while Alpine-age compression lead to the formation of a dense net of mylonites. The associated deformation, both distributed at the scale of the Bielsa massif and localized at decametric scale in mylonitic corridors, precedes the strain localization along the major thrusts of the Axial zone. The Bielsa massif is a good example where, inherited, pre-orogenic upper crustal softening controls the deformation patterns in granitic basement units through low-grade metamorphic reactions.

Key words: U-Th/Pb anatase-titanite-monazite dating, mylonites, chlorite-white mica thermobarometry, Bielsa, Axial zone

## 1. INTRODUCTION

Granites deformed at the brittle-ductile transition show mineral assemblages characteristic of low-grade metamorphism. Greenschist-facies metamorphic reactions often result in the growth of phyllosilicates (e.g. white mica, chlorite) whose presence strongly affect the rheological behaviour of the upper crust through softening, strain localization and fluid migration (Tullis, Yund, & Farver, 1996; Ingles, Lamouroux, Soula, Guerrero, & Debat, 1999; Jackson, Austrheim, McKenzie, & Priestley, 2004; Wintsch, Christoffersen, & Kronenberg, 2005; Goncalves, Oliot, Marquer, & Connolly, 2012). The breakdown of 80 % of feldspar into white mica, for example, reduces the depth of the brittle-ductile transition by two thirds (Gueydan, Leroy, Jolivet, & Agard, 2003). Reactions forming low-grade mineral assemblages responsible for crustal softening are generally observed to be syn-kinematic, occurring during the major deformation phases of an orogenic cycle (Wayne & McCaig, et al., 1998; Gueydan et al., 2003; Mansard, Raimbourg, Augier, Précigout, & Le Breton, 2018). Static or quasi-static hydrothermal alteration is also observed in granites and has been widely documented, especially in large igneous provinces (e.g. Parneix, Beaufort, Dudoignon, & Meunier, 1985; Cathelineau et al., 1986; Yuguchi, Sasao, Ishibashi, & Nishiyama, 2015). However static alteration is rarely characterised, and hardly ever dated and placed in a regional orogenic context. Indeed, low-grade metamorphic reactions often leave tenuous fingerprints only hinted at by equivocal microtextural relationships, especially in granites (e.g. Airaghi et al., 2017b), which are generally considered poorly reactive rocks at temperatures below 400°C.

At a microscopic scale, pre-kinematic and syn-kinematic transformations are difficult to distinguish, particularly so if the rocks have been deformed through several orogenic cycles.

The timing and conditions of pre-kinematic metamorphic reactions and their effects on (i) the syn-kinematic transformation and (ii) the rheological response of the upper crust to successive compressive phases remain therefore poorly constrained. This study addresses these issues by focussing on the Bielsa massif, a Variscan granite located in the Axial Zone of the central Pyrenees (Figure 1a). This massif is an excellent natural laboratory to study how granitic rocks record distinct low-grade metamorphic events. The massif is part of the central Pyrenean belt, which experienced at least two well-known deformation phases (Late Variscan and Alpine/Pyrenean, Cochelin et al. 2017), which are difficult to distinguish in the Axial zone (Cochelin et al, 2017). The Bielsa massif is located in the most external basement domain of the Pyrenees (implying it experienced the lowest peak metamorphic temperatures with respect to Alpine tectonics), south of the zones of large-scale shear bands that have affected other granitic basement units of Pyrenees (e.g. Maladeta, Néouvielle; Wayne & McCaig, 1988). In addition, structural and microstructural studies show significant distributed shortening at the scale of the massif (Román-Berdiel et al., 2004; Bellahsen et al., 2019), raising questions about the link between low-grade metamorphism and strain accommodation mechanisms. Early feldspar destabilisation has been proposed to have a major control on subsequent mechanical softening in Bielsa (Bellahsen et al., 2019), but the conditions and the age of such reaction still remains unconstrained.

In this contribution we estimate the conditions of crystallization of both pre-kinematic and syn-kinematic greenschist-facies mineral assemblages in the Bielsa granite and its Triassic sedimentary cover. Microstructural and petrographic analyses were combined with low-temperature thermobarometry and *in situ* U-Th/Pb dating of zircon, titanite and monazite. Attempt to date anatase (polymorph of rutile) by the U/Pb method were also undertaken. The implications for the timing of crustal softening relative to the major shortening phases are discussed with respect to their associated mineral assemblages. Results suggest that pre-

103 kinematic (pre-Alpine) alteration controls the deformation pattern and strain localisation in the  
 104 Bielsa granite during Alpine shortening.

105

## 106 **2. THE BIELSA MASSIF IN THE AXIAL ZONE (CENTRAL PYRENEES)**

107 The Axial zone (central Pyrenees) is part of a S-verging thrust system made of  
 108 imbricated thrust units stacked during the Late Cretaceous-Early Miocene collision of the  
 109 Iberian and European plates (Figure 1a). The plutons of the Axial zone (i.e. Bielsa, Neuville,  
 110 Maladetta massifs etc., Figure 1a) were emplaced into Paleozoic sediments during Late-  
 111 Variscan (320-300 Ma, e.g. Paquette, Gleizes, Leblanc, & Bouchez, 1997; Vacherat et al., 2017).  
 112 These plutons and their Paleozoic sedimentary cover constitute the basement to the Permian  
 113 and Mesozoic sedimentary units (Fig. 1a). Several tectono-metamorphic stages are documented  
 114 in the metasedimentary units Axial zone but are difficult to distinguish within the basement.  
 115 Recent studies have proposed that the majority of the deformation in the Axial zone is of  
 116 Variscan age (Cochelin et al., 2017). Cretaceous hydrothermal events have been identified in  
 117 the eastern Axial zone (Fallourd et al., 2014; Boutin et al., 2015) and related to extensive  
 118 tectonics centered on the SE Bay of Biscay. Basement thrusts in the central-western Pyrenees  
 119 (named Gavarnie and Guarga thrusts) were (re)activated during the Eocene to Miocene (20-30  
 120 and 32-36 Ma respectively, Jolivet et al., 2007; Elmola et al., 2018 and references therein). In  
 121 the hanging wall of the Gavarnie thrust, an older deformation event (*c.* 48 Ma) is recognised in  
 122 the massifs of Néouvielle and Eaux Chaudes. It has been associated with the activation of  
 123 mylonitic shear bands (e.g. Wayne & McCaig, 1998).

124 This study focusses on the Bielsa massif, mainly constituted by a pluton emplaced at *c.* 305 Ma  
 125 (Vacherat et al., 2017), in the S-verging thrust system structurally located between the Gavarnie  
 126 and Guarga thrusts (Figure 1b). Close to Lake Urdiceto (Figure 1c-d), granitic to granodioritic  
 127 rocks (Román-Berdiel et al., 2004) are unconformably overlain by Triassic continental red

128 sandstones and pelites. The basement and its sedimentary cover were deformed (folded) during  
 129 the Alpine compressional phase (Figure 1d, Casas et al., 2003; Román-Berdiel et al., 2004,  
 130 Bellashen et al., 2019) with a wavelength of ~1 km. Several sub-vertical S- or N-dipping normal  
 131 or reverse steep faults bound the antiforms and synforms (Figure 1d). In the core of the synforms,  
 132 Triassic sediments crop out. They exhibit a sub-vertical to N-dipping cleavage (e.g. Figure 2b  
 133 and 3c), with north side up sense of shear kinematic indicators above the sediment-cover  
 134 interface (Bellahsen et al., 2019). The granitic basement is heterogeneously deformed. At the  
 135 decametric scale, undeformed and weakly deformed granitic rocks alternate with zones of  
 136 distributed ductile deformation, zones of fracturing and faulting and mylonites (Figures 1c-d  
 137 and 2a-f). A pervasive N-dipping schistosity is widespread in the basement (Figure 2a-c and e).  
 138 Mylonitic corridors, with 1-2 m wide, are observed within the basement and at its boundary  
 139 with the Triassic sedimentary cover (Figure 2a-c). Mylonitic corridors alternate with less  
 140 deformed rocks with a wave length of ~100 m (Figure 1c) and they are characterized by  
 141 pervasive schistosity (S) and steep, N-dipping (45-70°) and S-dipping (55-70°) shear planes (C)  
 142 associated either with a north or with a south-verging movement (Figure 2a-e). In some shear  
 143 zone, the dips of mylonitic planes varies from S-dipping to N-dipping, with an apparent sense  
 144 of shear from top-to-north to top-to-south (Figure 2b-d). Some of the shear bands at the  
 145 boundary between the Triassic sediments and the late Variscan granite (regionally trending  
 146 N110, Figure 1c) contain deformed fragments of the Triassic red sandstone (Román-Berdiel et  
 147 al., 2004; Figure 2b), indicating that they are post-Triassic. The high density of mylonitic  
 148 corridors and the pervasive schistosity development result in a distributed deformation pattern  
 149 (as observed in other crystalline units as the Aar massif, Wehrens et al., 2017). The  
 150 granitic/granodioritic basement (regardless of the intensity of the strain) is pervasively hydrated  
 151 and the original magmatic mineral assemblage is partly to totally replaced by greenschist-facies  
 152 minerals. The steep topography of the massif allows one to infer that the latter replacement



affects the pluton at least over a topographic vertical profile of 2 km from the lowest outcrop of the massif (yellow stars in Figures 1b).

At the boundary between the Triassic sediments and the granite/granodiorite, sub-horizontal quartz and chlorite-bearing veins which are 1-5 cm-wide are observed (yellow square in Fig. 3b). Fifty meters from the contact, Triassic sediments show two generations of chlorite- and quartz-bearing veins: (1) sub-horizontal veins parallel to the ones observed at the contact between the basement and the sedimentary rocks produced by vertical extension, locally folded and associated with a crenulation cleavage (N184S) and (2) sub-vertical veins (Figure 3c).

### 3. SAMPLE DESCRIPTION AND CHRONOLOGY OF MINERAL ASSEMBLAGES

Twenty-seven samples were collected along two transects east and west of Lake Urdiceto, from the undeformed granite (e.g. ZA16-84 and B11-16, Figure 4a, b) up to the zone of intense mylonitisation (e.g. ZA16-96, ZA16-98; Figures 1c, 4g). One sample (ZAL18-11) was collected at the contact between the Triassic sandstones and a basement-hosted vein (Figures 3b). Two samples (ZA16-12 and ZA16-13) were collected in the Triassic sediments (Figures 3c).

#### 3.1 Samples from the basement

In the basement unit, we distinguished the following rock fabrics: *Undeformed* samples (e.g. ZA16-84, Figure 4a), where the magmatic, euhedral shape of grains is still preserved. *Weakly deformed* rocks (e.g. Figure 2f and 4c) exhibiting a weak yet pervasive schistosity (at an outcrop scale: S in Figure 2a). In some of those samples the schistosity is associated to mm-scale fractures (e.g. ZA16-82, ZA16-78, ZA16-128, Figure 4e-f and h) that are parallel to the subvertical shear planes observed at an outcrop scale in mylonites (C in Figure 2a). *Mylonites* showing S and C planes (e.g. ZA16-133, Figure 4g), where the C planes are as pervasive as S.

In the samples defined as mylonite, both brittle and ductile deformation features are identified, with the brittle ones underlined by fractures parallel to the shear planes C (Figure 4g).

All samples, regardless of the degree of the strain, exhibit extensive alteration of the magmatic mineral assemblage originally defined by quartz, K-feldspar and plagioclase, biotite  $\pm$  amphibole, apatite, zircon (all in textural equilibrium, Figures 4a-b) and ilmenite preserved as inclusions in the less altered amphibole and biotite grains (Figure 5a-b). The alteration is comprised by the breakdown of plagioclase and K-feldspar into white mica (10-30  $\mu\text{m}$  in size) + albite + calcite  $\pm$  rare epidote (Figure 4a, c, e-f). Biotite and amphibole break down to chlorite flakes (ChlA, abbreviations are from Whitney & Evans, 2010)  $\pm$  white mica (20-100  $\mu\text{m}$  in size)  $\pm$  prehnite (Figure 4a) and a Ti-bearing phase (anatase or titanite or both, Figure 4b, d, f and g). In the paragraph below, mineral assemblages are described in relation to their microstructural evolution from the undeformed granites and granodiorites to mylonites.

In the undeformed samples, relicts of feldspar, biotite and amphibole are still visible and their euhedral magmatic grain shapes are preserved (Figure 4a). Chlorite flakes (ChlA) grow at the grain boundaries of parent minerals and along biotite cleavages, and they are associated with a Ti-bearing phase (see below)  $\pm$  prehnite  $\pm$  K-feldspar (Figure 4a-b). Ilmenite grains are preserved in unaltered biotite and amphibole domains (Figure 5a). Quartz grains contain sparse, micrometric fluid inclusions and are cross-cut by microcracks. Allanite is locally observed in textural equilibrium with the magmatic minerals. Euhedral magmatic zircon grains are found within relicts of feldspar or at the boundaries between feldspar and amphibole. Cathodoluminescence imaging of zircon in samples ZA16-84 and ZA16-119 typically reveals primary oscillatory growth zoning without internal complexity. However, some zircon grains, especially in sample ZA16-119, show metamictization with porous domains and lobate rims 5-20  $\mu\text{m}$  thick, and very low cathodoluminescence emission (Figure 5d). In the weakly deformed samples, feldspar is pervasively sericitized (up to 80-90%). Original biotite grains are

203 chloritized between 70-90% (Figure 4c). Chlorite flakes (ChlA) and secondary reaction phases  
 204 (quartz, Ti-phase  $\pm$  white mica) are oriented parallel to the main schistosity and tightly folded  
 205 to form kinks (Figure 4d). Quartz grains partly preserve their magmatic texture, but are  
 206 fractured, with fractures subparallel to the kink axes. Grains are cross-cut by fluid inclusion  
 207 trails. Originally euhedral grains of ilmenite are first altered to aggregates of anatase + calcite  
 208 then to titanite (Figure 5a-b), following the reaction proposed by Hansen, Reimink, & Harlov  
 209 (2010) for low temperature conditions. Anatase is itself replaced by titanite, in textural  
 210 equilibrium with chlorite flakes (Figures 5a-b). Anatase and titanite are systematically aligned  
 211 with the chlorite flakes, within the S-planes. When they are folded to form kinks, anatase relicts  
 212 are mainly preserved in the microfold hinges (Figure 5c). In some of the weakly deformed  
 213 samples, titanite is the major Ti-bearing phase preserved (samples ZA16-119, B11-16, ZA16-  
 214 77 and ZA16-84).

215 In weakly deformed samples showing millimetric fractures, biotite deformation and  
 216 stretching along the main schistosity S is more pronounced (e.g. Figure 4e). Calcite is present  
 217 in the matrix. Fractures 1-3 mm thick displace the folded chlorite flakes to form en-echelon  
 218 microstructures (Figure 4e). These fractures are filled with secondary chlorite (ChlB)  $\pm$  white  
 219 mica (Figure 4f). Sheets of ChlB are oriented parallel to the fracture walls in contrast to ChlA  
 220 grains which are mainly perpendicular (Figure 4f). Furthermore, ChlB is rarely associated with  
 221 biotite breakdown products as prehnite and Ti-bearing phases (Figure 4f). Quartz grains are  
 222 both fractured and stretched, they exhibit undulose extinction and abundant fluid inclusion trails.  
 223 Titanite is observed in the same microstructural position as in undeformed samples (folded  
 224 within ChlA flakes). The microstructural position of anatase is instead more variable. Anatase  
 225 is observed: (1) as  $\sim 70$   $\mu\text{m}$  sub-euhedral relicts in titanite cores at the rims of the ChlA flakes  
 226 (as in the undeformed samples, type-1 Ant, Figure 4h, 5b-c, f-h and Figure S1) and (2) as grains  
 227 20-30  $\mu\text{m}$  in size not associated with titanite within ChlA flakes along the ancient biotite

cleavages (type-2 Ant, e.g. Figure 4h, 5f-h and Figure S1). Locally, type-2 anatase is observed within ChlB-bearing fractures (e.g. ZA16-73, Figure 5i). Type-2 anatase of type 2 is often observed close to type-1 anatase. Magmatic accessory minerals such as apatite and zircon are fragmented and stretched along the S planes.

In mylonitic samples, the schistosity is defined by folded chlorite + white mica flakes and interconnected layers of white mica (Figure 4g). Flakes are folded up to kinks. Shear planes (C) form at high angle with the main schistosity S (Figure 4g-h). The kink axes are kinematically compatible with shear movement on the C planes. Quartz grains are partially stretched and most of them are fractured, with cracks subparallel to the C planes (Figure 4g). Within the grains, evidences of ductile deformation are observed such as deformation lamellae. A larger amount of fluid inclusions in quartz are observed with these samples compared to weakly deformed samples. In mylonites (ZA16-96, ZA16-98), only one type of anatase is observed (small anatase grains of type 2 predominate). In these samples, monazite grains, 10-40  $\mu\text{m}$  in size, were identified in mylonites (sample ZA16-98 and ZA16-88). These monazite grains are wrapped by secondary chlorite and white mica (suggesting post-magmatic origin). The largest grains of monazite (20-40  $\mu\text{m}$ ) (Mnz1) are lobate, and stretched along the C planes with fractures perpendicular to them and exhibit irregular grain boundaries, micrometric large fractures, patchy textures with bright and dark spots in BSE images and ‘inclusion-like dissolution figures’ (as described by Grand’Homme et al., 2018; Airaghi, Janots, Lanari, de Sigoyer, & Magnin, 2018, Figure 5c). Small monazite grains ( $\sim 10$   $\mu\text{m}$ ) with rounded shape share features with that of ZA16-88, aligned along the main foliation or within alteration halos marking the reaction front along secondary fractures subparallel to the C (Figure 5j). In sample ZA16-98 monazite is locally Th and Si-enriched (tending towards a thorite composition, inset in Figure 5i).

In summary, the granitic rocks experienced a first transformation of the original magmatic mineral assemblage of  $Qz + Fs + Pl + Bt \pm Amph (+ Ilm + Ap + Zr \pm Aln)$  to  $Qz + ChlA + Ti\text{-phase} (Ttn \text{ or } Ant \text{ then } Ttn) \pm Pr \pm KFs$ . Zircon and titanite grains with anatase core (type-1 Ant) are stretched in the main schistosity and folded during shearing. They therefore predate any deformation stage. ChlB is rarely associated with secondary reaction products and helps to define the C-parallel fractures. It is considered to precipitate from a fluid during a second syn-kinematic (syn C planes) alteration event. The varying characteristics of anatase, only found in deformed samples, suggest that in these samples two generations of anatase may be preserved. That type-2 anatase is located within ChlA flakes along former biotite cleavage suggests that type-2 Ant grew after type-1 Ant on ChlA rims. The chloritization reaction front and replacement is indeed expected to progress from the grain boundaries to the core, along the biotite cleavages. The proximity of type-2 anatase to type-1 anatase grains indicates however transport scale of the anatase-forming elements limited to some dozen of  $\mu m$ . In sample ZA16-73 (discretely deformed). Type-2 Ant is observed in C-parallel fractures (Figure 5i). Type-2 Ant may have crystallized during the shearing. Mnz1 is affected by deformation and mainly observed within the main schistosity, while Mnz2 (and type-2 Ant, see below) are associated with C parallel fractures. Mnz2 is therefore syn C planes forming stage.

### 3.2 Samples from Triassic sediments and at the boundary between sediments and the granodiorite

At the brecciated contact between the Triassic sediments and the chlorite-quartz bearing vein in contact with the basement (Figure 6a), the Triassic sediments are composed of quartz, chlorite, white mica, Fe-oxides and clasts in a calcite matrix (sample ZAL18-11). The vein is composed of mm-size quartz grains recrystallized by bulging and hosting a dense net of fluid inclusions, interlayered with elongate chlorite and white mica ( $\pm$  calcite) (Figure 6b). Along

chlorite grain boundaries, abundant Fe-oxides, 20-40  $\mu\text{m}$  large anatase grains, monazite, REE-bearing carbonates and tourmaline are occasionally observed (Figure 6b). The textural aspect of monazite in sediments is similar to that of monazite in the basement (inset in Figure 6b).

The red-coloured, foliated pelitic rocks are comprised of white mica, chlorite and quartz grains on the scale of tens of microns ( $\pm$  detrital monazite, apatite and anatase, samples ZAL18-12 and ZAL18-13). The veins are approximately 100  $\mu\text{m}$  thick, they opened at high angle with the foliation and are filled by elongate grains of quartz rich in fluid inclusions (in the core of the vein). Chlorite developed along the vein-host rock interface with long axes parallel to the vein opening direction (Figure 6c). Veins are stretched and displaced by 30-50  $\mu\text{m}$  secondary chlorite and quartz-bearing layers cross-cutting the foliation, forming 'en échelon' fractures (Figure 6c-d). Monazite in pelites forms euhedral grains 5-10  $\mu\text{m}$  in diameter, sometimes in association with Fe-oxides and xenotime at the interface between the veins and host-rock.

#### 4. ANALYTICAL AND COMPUTATIONAL METHODS

The chemical composition of metamorphic chlorite and white mica has been analysed with a CAMECA SX-FIVE electron probe micro-analyser (EPMA) at ITeP (Sorbonne Université). Point measurements were made under a 15 kV acceleration voltage and 10 nA beam current with a  $\sim 1\mu\text{m}$  beam size, in wavelength-dispersive spectroscopy (WDS) mode, using diopside (Ca, Mg, Si),  $\text{MnTiO}_3$  (Mn, Ti), orthoclase (K, Al), hematite (Fe), albite (Na) and  $\text{Cr}_2\text{O}_3$  (Cr) as standards for measuring the elements written in parentheses. The compositional variability of chlorite and white mica in different microstructural sites was characterised by element mapping using both the EPMA and a Zeiss SUPRA-55VP scanning electron microscope (SEM) at ITeP (Sorbonne Université). EPMA elemental maps were acquired in WDS mode at 100 nA beam current, 15 keV acceleration voltage with a 200 ms dwell time. SEM maps were acquired in energy-dispersive spectroscopy (EDS) mode at 15 keV acceleration voltage, 30 nA

beam current with a dwell time of 256  $\mu$ s. SEM and EPMA maps were quantified with the software XMapTools (Lanari et al., 2014). The U, Th, Pb and REE contents of monazite were analysed with the JEOL-JXA-8230 EPMA at ISTERre (University of Grenoble), at 15 keV acceleration voltage, 200 nA beam current with a spot beam size. For each monazite analysis, a chemical U-Th/Pb age was determined and the average age of different populations of monazite (identified on the base of compositional criteria) was calculated with the software NiLeDAM. The analytical protocol and data processing are detailed in Appendix 1.

Titanite, anatase and zircon were dated *in-situ* by the U-Pb LA-ICP-MS technique at Trinity College, Dublin (Ireland), on the same thin sections as used for the microstructural and petrological studies. U-Pb ages were determined using a Photon Machines Analyte Exite 193 nm ArF Excimer laser-ablation system with a Helex 2-volume ablation cell coupled to an Agilent 7900 ICPMS. For titanite, zircon and anatase, 300 shots were ablated per analysis with a laser spot size of 24  $\mu$ m (Figure S1). The laser repetition rate and fluency were set at 15 Hz, 1.60 J/cm<sup>2</sup> and 11 Hz and 2.25 J/cm<sup>2</sup> for anatase/titanite and zircon respectively, and typically 50 analyses were obtained on each sample (usually 1-2 spots per grain) and plotted on a Tera-Wasserburg diagram (Tera and Wasserburg, 1972) with 2 $\sigma$  error ellipses, allowing determination of the initial Pb intercept on the <sup>207</sup>Pb/<sup>206</sup>Pb axis.

The raw titanite and anatase isotope data were reduced using the “VizualAge UcomPbine” data reduction scheme (DRS) of Chew, Petrus, and Kamber, (2014). The “VizualAge” DRS was employed for zircon data reduction. Common Pb in the titanite and rutile standards was corrected using the <sup>207</sup>Pb-based correction method. For unknowns, the initial Pb in titanite and anatase was determined from the upper intercept (y-intercept on the <sup>207</sup>Pb/<sup>206</sup>Pb axis) of the discordia line defined by the analyses on Tera-Wasserbutg Concordia. The age for each population of grains was calculated from the lower intercept of the discordia line on Tera-Wasserburg Concordia. line with the Pb evolution model. Zircon ages were instead

estimated by calculating the weighted average of  $^{206}\text{Pb}/^{238}\text{U}$  corrected ages (Table S3). The primary standards employed, the secondary standard ages and further details on the analytical procedure are reported in Supplementary Material S1. Titanite and anatase included in ilmenite were not dated due to their small size. When anatase core relicts were preserved in titanite grains (type-1 Ant), it was rarely possible to ablate separately relicts of anatase and their titanite host due to the small grain size (e.g. Figure S1). In anatase-dominated samples, where the bulk of grain was anatase, these analyses were classified and processed as anatase, in titanite dominated samples with only minor relict anatase the analyses were classified as titanite. The contribution of relicts of anatase to the calculated age was estimated by comparison with results from samples where the only anatase or titanite only were sampled. In sample where two types of anatase were observed, all anatase data were processed together. The existence of one or two population(s) of anatase based on the data interpretation was compared to microstructural observations.

Monazite ages were calculated from the EPMA U, Pb and Th contents. The associated detection limits were 90 ppm for Pb, 120 ppm for U and 115 ppm for Th. For each monazite analysis, a chemical U-Th-Pb age was determined (see Montel et al., 1996). When the Pb content was lower than the EPMA detection limit, a value of 90 ppm was used to estimate a maximum age.

The crystallization temperature and the minimum content of  $\text{XFe}^{3+}$  ( $\text{Fe}^{3+}/(\text{Fe}^{2+} + \text{Fe}^{3+})$ ) of each generation of chlorite in 23 selected samples were estimated using the Chl-Qz-H<sub>2</sub>O thermodynamic model of Vidal et al. (2006) from element abundances at a reference pressure of 3 kbar and H<sub>2</sub>O activity at fixed unit value. The absolute uncertainty on the crystallization temperature estimates is around 50°C (Vidal et al., 2006; Dubacq, Soret, Jewison and Agard, 2019), although the relative uncertainty between samples is likely lower (10-20°C). The semi-



empirical thermometer of Bourdelle, Parra, Beyssac, Chopin, and Vidal (2013) formulated for low-temperature chlorite was used for comparison.

## 5. RESULTS

### 5.1 Composition of pre-kinematic and syn-kinematic chlorite and white mica

Chlorite generally exhibits compositional variation at the  $\mu\text{m}$ -scale with high variability in Fe, Mg and Al contents (especially in discretely deformed granites), as shown in Figure 7 (and Table S1). In samples collected east of Lake Urdiceto, two groups of chlorite are recognized. The first, named Chl1, is ubiquitous from undeformed granites (pre-kinematic) to mylonites, and mainly observed in ChlA flakes (Figure 7a). It should be noted that Chl1 refers to a chemical composition while ChlA refers to the microtexture of chlorite (which do not necessarily correspond, e.g. Vidal et al., 2006; Airaghi et al., 2017). Chl1 is Al-poor (2.2-2.4 apfu) and Mg-rich (1.7-2.5 apfu). The second group of chlorites, Chl2, is mainly observed in syn-kinematic ChlB (Figure 7a, c-d) and exhibits higher Al content (Al= 2.5-2.86 apfu) and lower Mg content (Mg= 1.5-1.7 apfu). The Fe content increases slightly from Chl1 (2.15-2.3 apfu) to Chl2 (2.4-2.5 apfu). In undeformed samples, only homogeneous Chl1 in chlorite flakes is observed (e.g. sample ZA16-84). In the most deformed samples, chlorite flakes (ChlA) exhibit  $\mu\text{m}$ -scale Mg and Al zoning and portions of Chl1 are pseudomorphically replaced by Chl2. Chl1 is also found as relicts in ChlB in fractures, wrapped by Chl2 (Figure 7a). In samples collected west of Lake Urdiceto, Chl1 in flakes is Fe-rich (1.97-2.13 apfu) and Mg-poor (2.18-2.47 apfu) compared to Chl2 in veins and along fractures (Fe= 1.39-1.50 apfu, Mg= 2.83-2.95 apfu) (Figure 7b, c, e) while the Al content is typically constant (Table S1). A micron-scale zoning within Chl1 flakes is observed miming cleavage planes of the original magmatic crystal (biotite or amphibole) in discretely deformed samples, while Chl2 within ChlB within fractures

is homogeneous (Figure 7b). In mylonites, chlorite shows intermediate compositions (e.g. sample ZA16-96 in Figure 7c) difficult to relate to a specific microtextural sequence due to extensive deformation. In the Triassic sediments, chlorite is Al-enriched compared to chlorite in the basement, but exhibits similar compositional trends (Figure 7c-e). Two groups are recognized in samples ZAL18-13 and ZAL18-12: one is Mg-depleted (1.7-1.97 apfu) and Al-enriched (2.90-2.92 apfu) and is observed in veins, the other is Mg-enriched (2.18-2.40 apfu) or Al-depleted (2.68-2.78 apfu) and is observed within the matrix (Figure 7c-e). Only the second group of chlorite is observed in sample ZAL18-11 (Table S1).

White mica in the granitic basement shows 55-80 % muscovite (*Ms*), pyrophyllite (*PrI*) content in the 0-20% range and up to ~30 % celadonite content (*Cel*, Figure 8a). White mica in fractures, veins and in the deformed matrix (syn-kinematic) exhibits lower muscovite (55-70 %) and higher (or similar) celadonite content (20-30 %) than white mica in chlorite flakes (pre-kinematic, 70-80 % muscovite, 10-20 % celadonite, Figure 8a). The composition of white mica in sedimentary samples is similar to that of white mica from feldspar in basement samples (Figure 8b), but with lower variability. While in samples ZAL18-12 and ZAL18-11 one single group of white mica is observed, in sample ZAL18-13 two groups are identified: white mica in the veins have higher celadonite contents (18-28%) than in the matrix (10-18%).

## 5.2 Thermobarometry of low-grade fluid-rock interaction events

Thermodynamic modelling was combined to empirical thermobarometry to distinguish the conditions of crystallisation of the different generations of chlorite and white mica possibly recorded by the restricted range of compositional variations. Crystallisation temperature calculated with the chlorite thermometers of Vidal et al. (2006) and Bourdelle et al. (2013) are reported in Figure 9a, and range between 180 and 350°C. The minimum content of  $X_{Fe^{3+}}$  in chlorite calculated with the method of Vidal et al. (2006) ranges between 0.1 and 0.55, which

401 is realistic for low-T chlorite (Masci et al., 2019). The entire iron content was considered  
 402 divalent for the thermometer of Bourdelle et al. (2013) as recommended in that study.  
 403 Calculated temperatures for all groups of chlorites are in the same range, with small but  
 404 systematic differences between Chl1 and Chl2. In samples recording two compositional groups  
 405 of chlorites (that correspond to pre and syn-kinematic grains), where Fe variations prevail on  
 406 other element variations (ZA16-82, B11-19, ZA16-78), Chl1 records higher temperatures (220-  
 407 320°C) than Chl2 (180-250°C). In samples where dominant chemical variations involve Al and  
 408 Mg (ZA16-126, ZA16-73, B10-32), Chl1 records lower temperatures (170-280°C) than Chl2  
 409 (230-350°C, Figure 8a). In other samples (ZA16-133, B10-31), where two compositional  
 410 groups of chlorite were observed, calculated temperature cover the entire temperature range  
 411 estimated for all samples. Undeformed granite samples preserving only Chl1 (e.g. ZA16-79,  
 412 B11-16, ZA16-117) record the highest range of temperatures (280-350 °C). Crystallisation  
 413 temperatures calculated for chlorite in mylonites (e.g. ZA16-96, ZA16-98, ZA16-128, ZA16-  
 414 97) are intermediate between the Chl1 and Chl2 crystallisation temperatures. Two ranges of  
 415 temperatures were also obtained for chlorite in sedimentary samples (ZAL18-12). The highest  
 416 temperatures (240-350°C) are generally associated with chlorite in veins, while lowest  
 417 temperatures (180-280°C) are mostly associated with chlorites in C planes (with variability,  
 418 especially for samples collected Est and West of the Lake of Urdiceto, Fig. 1c). Only one range  
 419 of chlorite temperatures (Chl2, 200-300°C) is observed within the vein of sample ZAL18-11.  
 420 To test for the statistical validity of the two temperature intervals (240-350°C and 180-280°C),  
 421 3000 temperatures were randomly sampled from the dataset calculated with the thermometer  
 422 of Vidal et al. (2006) assuming a Gaussian error of  $\pm 30^\circ\text{C}$  (Figure 9b). In the basement, two  
 423 main peaks at 260 and 330°C persist. Scattered values at low-T conditions are attributed to  
 424 modelling artefacts due to  $\text{Fe}^{3+}$  overestimation and/or to departure of some chlorite  
 425 compositions from equilibrium with assumed unit activity for quartz and water.

The moderate celadonite contents of white mica (accounting for the Tschermark substitution only) suggest crystallization pressures in the range 1-4.5 kbar following the calibration of Massone and Schreyer (1988) (Figure 9c), as opposed to sub-surface hydrous alteration of feldspar only, which would favour pyrophyllitic substitution (Dubacq, Vidal, & De Andrade, 2010). Following this calibration, the higher celadonite content (and Si apfu content) of white mica in fractures, veins and shear bands indicates higher pressure conditions than in white mica growing from feldspar or from biotite (white mica in flakes, Figure 9c).

### **5.3 *In situ* U-Th/Pb dating of magmatic zircon and hydrothermal anatase, titanite and monazite**

Results for titanite, anatase and monazite dating are shown in Figure 10a-c and summarized in Table 1; the raw isotopic ratios and age data for zircon, titanite and anatase are provided in Table S3. The entire geochronological dataset is combined with previous literature age constraints of metamorphic events, derived from other localities of the Axial zone in Figure 10d. The composition of monazite together with all concordias for zircon, titanite and anatase are provided in Figure S2. Zircon analyses yield weighted mean Concordia ages at 300-310 Ma (Figure 10d and f). Some zircon analyses, especially in sample ZA16-119, exhibit Pb loss and broadly define a discordia line intercepting the Concordia at c. 285-290 Ma (see Figure S1).

Titanite grains contain on average 16 ppm of U, 1.7 ppm of Th and 50 ppm of common Pb, and exhibit a Th/U ratio of 0.1 with ages spanning from  $336 \pm 12$  to  $313 \pm 11$  (Figure 10a and d). Titanite in ZA16-84 provides the age constraint with the lowest uncertainty ( $313 \pm 11$ , MSWD of 1.1, Figure 10a) and exhibits the lowest common Pb content (10 ppm) and the highest Th/U ratio (0.20). Anatase contains on average lower amounts of U (8 ppm) and common Pb (24 ppm), and higher Th contents (3.4 ppm) than titanite, with Th/U ratios of 0.4, with ages from 301 to 48 Ma (Figure 10b and d). The age of anatase is difficult to constrain because of

high common Pb and low radiogenic Pb contents. When possible, two Tera-Wasserburg concordia lower intercepts for anatase U-Pb age data were defined for each sample, delimiting the possible youngest and oldest grain populations (e.g. Figure 10b). In this case, youngest ages cluster at *c.* 30-80 Ma while oldest ages cluster at *c.* 240-280 Ma (Figure 10b, d). The mylonitic granite ZA16-96 exhibits the young age population only (Tera-Wasserburg concordia lower intercept of  $39 \pm 8$  Ma, Figures 10c and S1), despite the low variability of the radiogenic U/Pb ratio.

Patchy monazite in samples ZA16-98 and ZAL18-11 shows low and variable U and Th contents (Figure 10e and Table S2), typical of low-temperature secondary monazite (Rasmussen & Muhling, 2007; Janots, Berger, & Engi, 2011). The U-Th/Pb ages (with Pb > EPMA detection limits of  $\sim 100$  ppm) range between 180 and 325 Ma (Figure 10c). In both samples, Pb-depleted domains (Pb < EPMA detection limits despite Th contents up to few wt%, Table S2) are observed within Th-depleted monazite grains, indicating late partial replacement of monazite grains by recrystallization and dissolution-reprecipitation (Figure 10e). The oldest ages generally correspond to monazite with relatively high Th content ( $\text{ThO}_2 > 2.4$  wt %) and variable U content ( $0.04 \text{ wt\%} < \text{UO}_2 < 1.0 \text{ wt\%}$ ). They cluster around  $254 \pm 6$  Ma. A second group of monazite has a lower Th content ( $\text{ThO}_2 < 1.9 \text{ wt\%}$ ), variable U content ( $0.01 \text{ wt\%} < \text{UO}_2 < 1.9 \text{ wt\%}$ ) and provides an age of  $196 \pm 18$  Ma. In both samples ZA16-98 and ZAL18-11 young ages are estimated from the Pb-depleted domains (Pb < detection limits). Assuming a Pb content equal to the EPMA detection limit ( $\sim 90$  ppm), a maximum age for this late stage crystallisation has been calculated at *c.* 100 Ma in sample ZA16-98 and at *c.* 20 Ma in sample ZAL18-11 for the domains with the highest Th ( $\text{ThO}_2 = 7.6 \text{ wt.}\%$ ) and U contents ( $\text{UO}_2 = 0.9750 \text{ wt.}\%$ ) (Figure 10c). Cenozoic ages of *c.* 50 Ma have also been estimated in sample ZA16-98 from thorite-monazite domains. No ages could be obtained for monazite from the sedimentary samples due to their low U, Th and Pb contents.

## 6. DISCUSSION

### 6.1 Evaluation of geochronological results

Estimated crystallisation temperatures are far below the closure temperature of Pb diffusion in rutile (580-630°C), titanite (575-700°C), monazite (~800 °C) and zircon (~900 °C, Rubatto, 2017; Engi, 2017 and references therein). Therefore, U-Th/Pb dates are interpreted as crystallisation ages. Zircon is dominantly of magmatic origin as attested by its microtextures. Concordant zircon ages, inferred to bracket the timing of the Bielsa pluton emplacement at 300-310 Ma (Figure 10d and Table 1), are in agreement with previously published ages (Vacherat et al., 2017). Zircon ages therefore constrain the upper limit of the first alteration event. Discordant ages defining a chord with an intercept at *c.* 290 Ma in sample ZA16-119 (Figure S1) derive from sampling of metamictic zircon domains, characterized by decreasing crystallinity, Pb loss and variable incorporation of common Pb. Since metamict domains show typical textures of dissolution-reprecipitation under low-T conditions (Geisler et al., 2003) and are observed in undeformed samples, the *c.* 290 Ma age may indicate re-opening of the system during the early pre-kinematic fluid-rock interaction, started shortly after the pluton emplacement, in Late Variscan times.

Titanite ages are less accurate but cluster within uncertainty of the zircon ages, at *c.* 300 Ma (Late Variscan) (Figure 10d and Table 1). Some of the titanite ages are older than the corresponding zircon ages from the same sample. The titanite Discordia line on Tera-Wasserbaur Concordia diagram is well constrained due to the large variation in U:Pb ratio of the titanite grains (Figure 10a and Figure S2). Therefore, the titanite ages marginally older than their corresponding zircon ages may originate from local incorporation of radiogenic Pb at the time of titanite crystallization (see also Essex and Gromet, 2000). The  $^{207}\text{Pb}/^{206}\text{Pb}$  initial ratio of metamorphic titanite has been shown to vary up to 2% in the same sample (Kohn, 2017), and

is often significantly lower (i.e. more radiogenic) than the crustal evolution model of Stacey and Kramers (1975). This signs the incorporation of radiogenic Pb from the breakdown of a U-rich mineral phase such as rutile or anatase, anatase being observed here as the most common titanite precursor.

The U/Pb ages obtained for anatase are less well constrained than the titanite due to higher common Pb, lower radiogenic Pb contents and the smaller spread in U-Pb ratio of the anatase grains. Calculated ages range between 40 Ma and 280 Ma. Anatase does not record the magmatic stage since it is observed to replace magmatic ilmenite. If type-1 Ant or titanite recrystallize into type-2 Ant, inter and intra-grain variations in the radiogenic Pb and U content could be inherited from the parent mineral given the small transport scales for anatase-forming elements deduced from microtextural evidence (see section 3.1). Such variations and possible incorporation of type-1 Ant in spot ablations of titanite (see section 4) contribute to the large spread of the anatase ages (e.g. samples ZA16-79, ZA16-73). However, a recurrently young signal of *c.* 40-80 Ma is exclusively observed only in samples with both types of anatase and in mylonites. As solid-state Pb diffusion can be excluded due to the low metamorphic grade, the youngest U-Pb anatase ages likely indicate partial (re-)crystallization of the smallest anatase grains (type-2 Ant), in agreement with microtextural observations. In addition, the upper limit of the range of anatase ages is the youngest in samples with both types of anatase: This suggests mixing at a smaller scale than laser beam size between older titanite-anatase and new anatase. The two age end-members are shown on Figure 10d for all anatase-bearing samples.

Monazite is unlikely to record the magmatic stage since (1) magmatic allanite and apatite incorporate the rare earth elements and phosphorous necessary for monazite crystallization, (2) monazite is observed to replace magmatic allanite or apatite and (3) the oldest monazite ages are younger than the zircon ages. Monazite ages in both samples ZA16-98 and ZAL18-11 indicate a series of events at *c.* 250 Ma, 200 Ma, and possibly < 50 Ma. This range of ages

suggests successive episodes of partial dissolution-reprecipitation, as also shown by the patchy textures and the dissolution figures of monazite grains (Figures 5c and 6b). The mineral assemblage corresponding to the monazite ages of *c.* 200 Ma remains difficult to identify as textural and chemical evidences is lacking. The ages of 190-250 Ma obtained in monazite of chlorite-bearing veins in sediments indicate that monazite grains were likely inherited from the underlying basement and partially re-crystallized during vein opening and fluid circulation soon after sediments deposition in Triassic times.

## 6.2 Timing and conditions of fluid-rock interactions and deformation

Detailed microstructural and petrological observations show a poly-phase alteration history in the Bielsa basement at temperatures below 350°C. Within this temperature range, a first fluid-rock interaction event is related to the breakdown of the original magmatic assemblage and the growth of Ttn, Chl1, anatase (type-1 Ant) at 270-350°C. This alteration event predates all deformation stages since the earliest deformation phase deforms this mineral assemblage and the alteration event is also observed in undeformed samples (e.g. Figure 4a-b). During the first alteration event, the source of Al and Ca for chlorite and titanite ( $\pm$  prehnite) growth is the contemporaneous breakdown of plagioclase and the albitization of alkali-feldspar (always largely consumed), irrespective of the strain intensity. Calcium may also derive from external fluids as attested by calcite growth within weakly deformed granite matrix. Titanite, zircon, anatase and oldest monazite ages allow bracketing the timing of the early alteration(s) to 230-300 Ma (late to post-Variscan). This age range is in agreement with  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of biotite of *c.* 280 and 250 Ma obtained in the Bielsa and Maladeta massifs respectively (Jolivet et al., 2007).

The second fluid-rock interaction event is related to the syn-kinematic growth of Chl2 during the formation of C-S structures (see section 3) at  $\sim$ 200-280°C. The pervasive schistosity, kinking, shearing and fracturing are likely to have occurred at the same time since they are



552 kinematically compatible. The S planes are observed in both the basement and in the Triassic  
 553 sediments (see section 2). The S-forming stage is therefore post-late Triassic in age at least.

554 In such deformed samples, the youngest ages are yielded by anatase (in samples bearing  
 555 both types of anatase) and by monazite; this suggests that deformation triggered the partial re-  
 556 crystallization of anatase and monazite. The youngest anatase ages only (*c.* 40 Ma) and the  
 557 youngest monazite ages (*c.* 50 Ma) are obtained in mylonites (ZA16-96 and ZA16-98). This  
 558 observation suggests that the mylonitization related to the deformation stage likely occurred  
 559 between 40 and 70 Ma. These ages are in agreement with Rb-Sr ages of *c.* 48 Ma obtained for  
 560 the (re)activation of mylonitic bands in the Néouvielle massif (~ 15 km to the northwest of  
 561 Bielsa, Wayne & McCaig, 1998). In sample ZA16-79 an age population at *c.* 120 Ma is  
 562 observed, but no clear textural relationships are identified, while the large uncertainties mean it  
 563 Eocene ages.

564 Chlorite temperatures calculated with the method of Vidal et al. (2006) and Bourdelle  
 565 et al. (2013) are consistent despite differences in how they employ the oxidation state of Fe.  
 566 The calculated range of temperatures (200-350°C) is also consistent with hydrothermal  
 567 conditions typically associated with the appearance of prehnite and titanite in the cleavages of  
 568 biotite (e.g. Eggleton & Banfield, 1985; Morad, Sirat, El-Ghali, & Mansurbeg, 2011; Yuguchi  
 569 et al., 2015) and with temperatures calculated for the overlying sediments, suggesting that fluids  
 570 were freely circulating between the basement and the overlying sediments. In details,  
 571 thermometric results indicate that the pre-kinematic greenschist-facies metamorphism occurred  
 572 at higher temperature (270-350°C) than later syn-kinematic fluid-rock interaction (200-280°C,  
 573 Figure 9b), with spatial variations (east and west of Lake Urdiceto, Figure 9a) due to local  
 574 variations in fluid composition. The systematic differences between temperatures estimated for  
 575 Chl1 and Chl2 support however the existence of two different fluid-rock interaction events.

The moderate celadonite content of white mica, especially in fractures, veins and shear bands (Figure 8a and c) suggests crystallization at a pressure of 1-5 kbar (1 - 4.5 kbar, following the formulation of Massone and Schreyer, 1988, Figure 9c and below 3 kbar according to Cathelineau et al., 1986 for hydrothermal alteration in granites). No paragonite nor margarite components are observed within our white mica dataset. Pyrophyllite substitution, which increases the Si content of muscovite, is not predominant compared to the Tschermak substitution (Figure 8a). Increasing pyrophyllite content in sample B11-31 implies crystallization during continuous cooling (Dubacq et al., 2010). Fluid inclusion trapping pressures in the range 2-5 kbar are reported by Henderson and McCaig (1996), consistent with pressure estimates from white mica in mylonite veins (Wayne & McCaig, 1998). The lowest pressure values of ~ 2 kbar are consistent with the maximum burial depth estimated for the Bielsa (Jolivet et al., 2007; Bellahsen et al., 2019).

This low-grade petro-chronological dataset allows the timing of low-grade metamorphism and deformation to be discussed in the light of the Variscan and Alpine orogenic cycles, with major implications for the crustal rheology and the evolution of the deformation style in granites.

### **6.3 Pre-orogenic alteration and implications for crustal softening prior to shortening**

Petro-chronological results and microstructural analyses show that Late to post-Variscan lower greenschist-facies metamorphism in the Bielsa massif transformed an initially strong assemblage made of plagioclase, K-feldspar (forming together close to half of the primary modal composition) and amphibole into weaker, hydrated minerals such as white mica and chlorite, without associated deformation (as suggested by Bellashen et al., 2019). The breakdown of feldspar to white mica decreases by up to two orders-of-magnitude the sustained shear stress (at a constant strain rate) at 400°C, lowering the depth of the brittle-ductile

601 transition by at least a third (Wintsch et al., 1995; Gueydan et al., 2003). In the Bielsa massif,  
602 pre-orogenic sub to lower greenschist-facies metamorphic reactions have two effects: they  
603 enhance grain size reduction (e.g. from magmatic feldspars to minute white micas) and also  
604 replace strong minerals such as feldspar and amphibole with mechanically weaker  
605 phyllosilicates (e.g. Shea & Kronenberg, 1993). Both processes are known to result in enhanced  
606 softening of the granitic rocks (e.g. Fitz Gerald & Stünitz, 1993; Wintsch et al., 1995; Oliot,  
607 Goncalves, Marquer, 2010). Early pre-kinematic alteration therefore considerably softened the  
608 granite at least 150 Ma before the major Alpine shortening phases. Furthermore, the massive  
609 growth of pre-kinematic and pre-Alpine white mica and chlorite indicates high fluid-rock ratios  
610 during Late-to post-Variscan times and may strongly influence the water availability in the  
611 rocks at the grain boundaries during deformation. This has been shown to have major effects  
612 on the mechanisms of strain accommodation in other major phases as quartz (e.g. Palazzin et  
613 al., 2018) and hence impact the deformation style.

614        Sericitisation of feldspar and chloritisation of biotite is observed to increase with  
615 deformation. This suggests that granite alteration continued during syn-kinematic Alpine  
616 shortening. In mylonites, syn-kinematic chlorite and white mica partly replace the pre-  
617 kinematic chlorite and mica grains, this time without needing huge supplementary amounts of  
618 external fluid. Consequently, in the latter fluid-rock interaction event, there is no evidence for  
619 additional large-scale reaction-driven softening outside mylonitic zones, consistent with  
620 observations reported for the Néouvielle massif (~ 15 km to the northwest, Wayne & McCaig,  
621 1998). The crystallisation of new phyllosilicates and the larger amount of fluid inclusions in  
622 quartz in fractured and mylonitic samples as well as the partial age resetting up to ~40 Ma close  
623 to shear zones also appear to indicate progressive localisation of metamorphism with strain  
624 localisation.

Zones of fractures and faults indicate that granitic rocks were also deformed by frictional behaviour, as commonly observed at temperatures of 200-350°C (e.g. Copley, 2017). The crystallization of phyllosilicates during a pre-orogenic alteration event may weaken fault zones by at least 30% as phyllosilicates have much lower coefficients of friction than undeformed and unaltered crystalline rocks (e.g. Kaduri, Gratier, Renard, Çakir, & Lasserre, C., 2017; Copley, 2017). The pre-existence of phyllosilicate in the Bielsa basement therefore appears to have generated a network of weak rocks with low friction coefficient resulting in their distributed deformation.

#### **6.4 Effect of the early alteration on deformation patterns at field scale**

The pervasive schistosity (S) observed within the Bielsa massif along the studied transects indicates that the deformation is distributed at the scale of the massif (Figure 1b). The existence of mylonitic corridors shows a phase of strain localization with variations in the sense of shear at the kilometric to decametric scale, but their high density also results in a distributed deformation at the massif scale. At Bielsa, both S and C forming stages post-date the Late to post-Variscan pervasive alteration that softened the basement. In the Maladeta massif, (50-60 km to the northeast), less pervasive pre-kinematic alteration is observed as well as localized deformation and lower density of mylonitic corridors (Leblanc, Gleizes, Lespinasse, Olivier, & Bouchez, 1994). This indicates that pre-orogenic crustal softening controlled the deformation patterns observed on a outcrop scale, in particular the frequency of mylonitic bands the location of faults and of fractures.

In the Bielsa massif, strain localization in mylonitic bands may have occurred during the intense folding of the basement and the sedimentary cover in the Eocene as indicated by the young ages from the mylonites. During this stage, the re-activation of steep faults may have served as fluid pathways and triggered alteration. Interfaces between differently-altered

domains formed different phase strength contrasts. Consequently, ductile strain and reactions interacted positively to produce narrow ductile shear zones (as described by Holyoke & Tullis, 2006). Furthermore, deformation at this stage may strongly influence the breakdown on residual feldspar to muscovite (e.g. Knipe & Wintsch, 1985), as attested by the greater amount of white mica observed in mylonites compared to weakly and undeformed samples.

The youngest ages obtained in this study (*c.* 40 Ma) are older than the activation of the Gavarnie and Guarga thrusts (Figure 1b), in the hanging and footwall of the Bielsa unit, dated at 32-36 Ma et 20-30 Ma respectively (e.g. Bosch et al., 2016; Elmola et al., 2018) and similar to the age of mylonitization in the Néouvielle massif (Wayne & McCaig, 1998). This may indicate that the distributed shortening in Bielsa and at a larger scale predates the localization of the strain along some of the major thrust of the Axial zone. These findings are consistent with the distributed / localized modes of shortening documented in the external Western Alps (Bellahsen et al., 2014), in the central Alps (Wehrens, Baumberger, Berger & Herweg, 2017) and in the Longmen Shan where pre-kinematic and a syn-kinematic greenschist-facies metamorphic events were also recognized (Airaghi et al., 2017b), indicating that they might be typical of the evolution of basement massif in the external domains of the orogenic wedges.

## **6.5 Onset and preservation of early alteration in granitic basement**

Late to post-Variscan fluid-rock interaction took place on the scale of the Axial zone as metamorphic reactions similar to those observed in the Bielsa massif are found in other crystalline massifs in the Pyrenees (e.g. Maladeta, Néouvielle, Col de Jau; Cathelineau, 1986; Boutin et al., 2016). The early alteration stages may be linked to protracted magmatic activity recorded in the Pyrenean domain throughout the entire Permian (Denèle, Paquette, Olivier, & Barbey, 2012). Late Variscan magmatic activity has also been invoked as the cause of hydrothermal alteration in the French Massif Central (Cathelineau, 1986; Turpin, Leroy, & Sheppard, 1990). Permian to Triassic ages similar to those obtained for fluid-rock interaction

events in the Bielsa massif have also been documented in the Variscan basement of the Eastern Iberian Central System and in NE Spain by fluid inclusion and isotopic studies (Tornos, Delgado, Casquet, & Galindo, 2000 and references therein). The associated hydrothermal alteration in these cases is related to hydrothermal cells formed during extensional tectonic events rather than to plutonism (Tornos et al., 2000; Cardellach, Canals, & Grandia, 2002). In the Bielsa massif, high fluid-rock ratios have been proposed to result from ingress of seawater and meteoric fluids during the extensional phase following the Variscan orogeny (McCaig, Tritlla, & Banks, 2000). This is consistent with the fact that the Bielsa basement was exposed at the surface before or during the Permian, as attested by the erosional unconformity between the basement and its sedimentary cover. The preservation of early alteration features in granites over two orogenic cycles (Variscan and Alpine) implies that the basement remained at low grade conditions for over 200 Ma. In the Pyrenees, the main post-Variscan metamorphic phase related to fluid circulation is dated at 110 Ma (e.g. Boutin, 2016). Although Cretaceous ages were obtained for samples which contain both types of anatase, the large U/Pb age uncertainties for this time period in our petro-chronological dataset mean that strong evidence for extensive fluid circulation, mineral replacement and deformation during Cretaceous times is lacking. This is in contrast to the eastern Pyrenees where a hydrothermal event characterized by newly formed rutile and titanite associated with Cretaceous rifting overprints the ‘post’-Variscan hydrothermal alteration assemblages (Figure 10d; Boutin et al., 2016; Fallourd et al., 2014). This may indicate that, within the Pyrenean belt, metamorphism related to rifting has only weakly affected the southern part of the Axial zone.

## 7. CONCLUSIONS

The granitic basement rocks in the southern Axial zone of the Pyrenees (Bielsa massif) acted as reactive rocks at low temperatures ( $T < 350\text{ °C}$ ) over a long (*c.* 300 Ma) polyphase history.

701 At an outcrop scale, the Bielsa pluton and the Triassic sedimentary cover exhibit a pervasive  
702 N-dipping schistosity, folded or associated to steep C planes localized within a dense network  
703 of mylonitic bands. Within the granitic basement, partial mineral replacement and  
704 compositional variations at the micron-scale record an extensive fluid-rock interaction event at  
705 ~270-350°C in Late to post-Variscan times (230-300 Ma), as indicated by the titanite, anatase  
706 and zircon U/Pb ages dataset. This event is ubiquitous and particularly well preserved in the  
707 less deformed areas of the massif. It is responsible for pre-kinematic (pre-Alpine) plagioclase  
708 and amphibole replacement with growth of phyllosilicates, some tens of million years after  
709 pluton emplacement. A second syn-kinematic fluid-rock interaction event is marked by the  
710 (re)crystallisation of phyllosilicates at ~200-280°C and is related to the formation of mylonitic  
711 corridors and fractures parallel to the C shear planes. In the most deformed samples, despite the  
712 low radiogenic Pb content, monazite and anatase U-Th/Pb ages systematically show a young  
713 age component at 40-70 Ma, coeval with the Alpine/ Pyrenean deformation in the southern  
714 Axial zone and related to the second alteration event. As the strength of phyllosilicate-rich  
715 material is lower by up to an order-of-magnitude than that of the original granite, the granitic  
716 massif was significantly softened (and hydrated) at least 150-200 Ma before the major Alpine  
717 shortening phase. The dense network of mylonites in the Bielsa pluton resulted in distributed  
718 deformation at the massif scale before the localization of the strain along the major thrusting  
719 systems of the Axial zone. Pre-orogenic crustal softening controlled the deformation patterns  
720 where strain and shortening localized during successive deformation events. Pre-orogenic  
721 greenschist-facies metamorphism is often poorly characterized compared to higher-grade  
722 metamorphic domains in mountain belts. The case of the Bielsa massif shows that moderate  
723 analytical effort can provide valuable information allowing for a better constraints on the  
724 rheological and thermobarometric evolution of basement rocks during the orogenic cycle, even  
725 at low-grade conditions.

726

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736

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914

915 **SUPPORTING INFORMATION**

916 Additional Supporting Information may be found online in the supporting information tab for  
917 this article.

918 Description Supinfo.doc/x

919 **Appendix S1.** Analytical methods for geochronology and monazite analysis

920 **Figure S1.** Example of location of laser spot for zircon, anatase and titanite dating.

**Figure S2.** Tera-Wasserburg diagrams for all analysed anatase, titanite and zircon. Concordia-discordia diagrams for zircon.

Dataset.xls/x

**Table S1.** Representative chemical composition of chlorite and white mica.

**Table S2.** Representative chemical composition of monazite in samples ZA16-98 and ZAL18-11.

**Table S3.** Original isotopic data for zircon, titanite and anatase. Graphs represents weighted mean zircon ages.

# **FIGURE CAPTION**

**Figure 1** Geological maps and cross section. (a) Schematic structural map of the Pyrenees, modified from Román-Berdiel, Casas, Oliva-Urcia, Pueyo, and Rillo, 2004. Red square: Bielsa, N: Néouvielle, M: Maladeta, J: Jau. (b) Schematic structural cross section of the Axial Zone (modified from Jolivet et al., 2007). Yellow stars indicate limits of the area where pervasive alteration of the original granite has been documented. Black rectangle denotes the studied area. (c) Geological map of the studied area. (d) Cross sections along transects AA' and BB'.

**Figure 2** Field structures around Lake Urdiceto. (a) Mylonitic corridor along the transect BB' of Figure 1c. White: schistosity (S), yellow: shear planes (C). (b) Second example of mylonitic corridor a few hundred meters eastward of transect BB', at the contact with the Triassic sediments. Schistosity (S, filled white lines) is subparallel to S-dipping shear planes (C, marked in yellow) due to high strain. (c) Mylonitic bands within the basement with C planes varying from S-dipping to N-dipping. (d) N-dipping shear planes in a mylonite at the contact between the basement and the sedimentary cover. (e) Enlarged view of mylonitic granite (see panel a for location). (f) Enlarged view of weakly deformed (but altered) granite (see panel a for location).



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947 **Figure 3** Field structures in the Triassic sediments. (a) Unconformity between the basement  
 948 and the Triassic sediments. (b) Chlorite-quartz bearing veins at the contact between the  
 949 basement and the basal breccia in the Triassic sediments. (c) Two generations of chlorite-quartz  
 950 bearing veins within Triassic sandstones and pelites.

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952 **Figure 4** Photomicrographs (a, c, e and g) and backscattered electron images (BSE) (panels b,  
 953 d, f and h) of granitic basement with increasing deformation. Abbreviations are from Whitney  
 954 & Evans (2010), except Wm: white mica; (a) Undeformed but altered granite; (b) BSE image  
 955 of a Chl + Wm + Ttn pseudomorph after Bt; (c) weakly deformed and altered granite with dark  
 956 Chl-Wm pseudomorphs after Bt folded to form kink bands; (d) BSE images of a kinked Chl  
 957 flake; (e) weakly deformed sample with opening fractures. Chlorite flakes are cross cut by  
 958 secondary mm-size fractures. (f) BSE image of a Chl + Ttn flake after Bt (Bt relicts still visible),  
 959 cross cut by a fracture filled with secondary chlorite; (g) mylonite; (h) folded Chl + Wm + Ant  
 960 flake cross cut by a secondary fracture in a highly deformed sample. Two types of anatase grains  
 961 are recognized.

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963 **Figure 5** Backscattered images of accessory minerals in the granitic basement. (a) and (b)  
 964 magmatic Ilm breaking down to Ant + Cal, then to Ttn. (c) Anatase 1 folded within a Chl flake  
 965 and replaced by Ttn. (d) Magmatic zircon (core) with metamict rims (low CL intensity) in  
 966 sample ZA16-119. (e) Chlorite flakes (ChlA) with type-1 Ant cross cut by ChlB-bearing  
 967 fractures with type-2 Ant (sample ZA16-73). (f) Type-2 Ant rimming titanite after anatase  
 968 (type-1 Ant, preserved in the core of titanite). (g) Chlorite flake (ChlA) in sample ZA16-79  
 969 with both types of anatase. (h) Relationships between titanite and anatase in sample ZA16-128.

(i) Monazite in sample ZA16-98. The inset image shows the patchy and porous aspect of the monazite grains. (j) Monazite in reaction halos around fractures in sample ZA16-88.

**Figure 6** Macro- and micro-scale petrography of the Triassic sediments. (a) Hand sample collected at the boundary between sediments and the granitic basement (ZAL18-11). (b) Backscattered electron image of panel a, showing the occurrence of anatase, Fe-oxides and Mnz within neocrystallized Chl and Wm. The inset show the patchy texture of monazite grains. (c) Chlorite-bearing veins and shear planes forming ‘en-echelon’ microstructures in sample ZA16-12. (d) Two generations of chlorite (in veins and shear planes) in samples ZA16-12 (zoom of panel c). ChlA and ChlB refer to chlorite flakes and chlorite in fractures/veins respectively but may be different in origin to ChlA and ChlB observed in the basement.

**Figure 7** Chemical composition of chlorite. (a) Quantified SEM map of  $\text{Al}_2\text{O}_3$  content in chlorite in sample B10-31 (mylonite). (b) Quantified SEM map of FeO content in chlorite of sample ZA16-82 (fractured sample). (c) Elementary Al vs Mg (%) content of all analysed chlorites; (d) Trends and compositional groups identified in chlorite in samples collected east of Lake Urdiceto; (e) Trends and compositional groups identified in chlorite in samples collected west of Lake Urdiceto.

**Figure 8** Chemical composition of white mica. (a) Compositional triangular plot and trends for white mica in the basement. (b) Compositional ternary diagram of white mica in the sedimentary samples. Mus: muscovite, Cel: celadonite, Pyr: pyrophyllite.

**Figure 9** Thermobarometric results. (a) Chlorite temperatures calculated with the method of Vidal et al. (2006) (circles) and Bourdelle et al. (2013) (rectangles). (b) Monte Carlo simulation

for the temperature dataset calculated for basement chlorite (3000 iterations, see the text for details). (c) Pressure range estimated from the celadonite content in white mica, following the calibration of Massonne and Schreyer (1988). This calibration does not consider the pyrophyllite content in white mica, as it is the case in the Bielsa granite. Pressure values should therefore be considered as minimum values.

**Figure 10** Geochronology results. (a) Representative Tera-Wasserburg concordia lower intercept age defined by titanite analyses in an undeformed sample (ZA16-84). (b) Tera-Wasserburg Concordia lower intercept ages defined by various anatase populations (red: old, blue: young) in a deformed sample (ZA16-128). (c) Frequency distribution of monazite ages. Note that youngest monazite ages are estimated from Pb depleted domains (Pb < EPMA detection limits of ~100 ppm) and monazite-thorite domains (see the text for details). Note the ages calculated for domains where Pb is below the EPMA detection limit are maximum ages. (d) Summary of geochronological results (this study) integrated with previously published data for metamorphic events in the Axial zone. U-Pb Ant-Ttn indicate the ages obtained for analysis where a titanite locally preserved anatase cores (type-1 Ant, see the text for details). (e) U and Th content of monazite in sample ZAL18-11. (f) Probability density plot of all zircon ages for samples ZA16-84 and ZA16-119 (2 $\sigma$  error).

**Table 1** Summary of sample descriptions and ages.