

Coexistence of enriched and modern-like 142 Nd signatures in Archean igneous rocks of the eastern Kaapvaal Craton, southern Africa

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Kröner

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1	Coexistence of enriched and modern-like ¹⁴² Nd signatures in Archean
2	igneous rocks of the eastern Kaapvaal Craton, southern Africa
3	Kathrin P. Schneider ¹ , J. Elis Hoffmann ¹ , Maud Boyet ² , Carsten Münker ³ , Alfred Kröner ⁴
4	
5	¹ Institut für Geologische Wissenschaften, Freie Universität Berlin, Germany (*kathrin.schneider@fu-
6	berlin.de)
7	² Laboratoire Magmas et Volcans, Université Clermont Auvergne, France
8	³ Institut für Geologie und Mineralogie, Universität zu Köln, Germany
9	⁴ Beijing SHRIMP Center, Institute of Geology, Chinese Academy of Geological Sciences, Beijing,
10	China, and Institut für Geowissenschaften, Universität Mainz, Germany
11	
12	Keywords
13	
14	¹⁴² Nd
15	Kaapvaal Craton
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19	Differentiation
20	
21	Abstract
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23	The short-lived ¹⁴⁶ Sm- ¹⁴² Nd isotope system is an important tool for tracing Hadean crust-
24	mantle differentiation processes and constraining their imprint on much younger rocks from Archean
25	cratons. We report the first comprehensive set of high-precision ¹⁴² Nd analyses for granitoids and
26	amphibolites of the Ancient Gneiss Complex (AGC; Swaziland) and the oldest metavolcanic units of

27 the Barberton Greenstone Belt (BGB; South Africa). The investigated samples span an age range from

3.66 Ga to 3.22 Ga and are representative of major geological units of the AGC and the lower 28 Onverwacht Group of the BGB. Measured samples yielded μ^{142} Nd values in the range from -8 ppm to 29 30 +3 ppm relative to the JNdi-1 terrestrial standard, with typical errors smaller than 4.4 ppm. The distribution of the μ^{142} Nd values for these 17 measured samples is bimodal with ten samples showing a 31 tendency towards slightly negative μ^{142} Nd anomalies, whereas seven samples have ¹⁴²Nd similar to the 32 terrestrial reference. The only confidently resolvable μ^{142} Nd anomalies were found in a 3.44 Ga 33 34 Ngwane Gneiss sample and in amphibolites of the ca. 3.45 Ga Dwalile Greenstone Remnant, revealing μ^{142} Nd values ranging from -7.9 ± 4.4 to -6.1 ± 4.3 ppm. The μ^{142} Nd deficits do not correlate with age, 35 lithological unit, or sample locality. Instead, our results reveal that two distinct mantle domains were 36 involved in the formation of the AGC crust. The two reservoirs can be distinguished by their μ^{142} Nd 37 signatures. Mantle-derived rocks tapped the enriched reservoir with negative μ^{142} Nd at least until 3.46 38 Ga, whereas the granitoids preserved a negative μ^{142} Nd signature that formed by incorporation of older 39 AGC crust at least until 3.22 Ga. The oldest gneisses with no μ^{142} Nd anomaly are up to 3.64 Ga in age, 40 indicating that a modern terrestrial ¹⁴²Nd reservoir was already present by early Archean times. 41

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43 1. Introduction

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45 Studying the first billion years of Earth's evolution is crucial for understanding the early 46 mantle and crustal differentiation history as well as crustal recycling processes. However, the lack of preservation of the Hadean (4.5-4.0 Ga) rock record hinders a direct study of early geodynamic 47 processes. The earliest relicts of potential continental crustal origin are zircon detrital grains from the 48 ca. 3.3 Ga Jack Hills metaquartzites in NW Australia, dating back to almost 4.4 Ga (e.g., Wilde et al. 49 50 2001). Metamorphosed felsic continental crust of Eo- and Paleoarchean age (4.0-3.2 Ga) is preserved 51 as grey gneiss terranes in all cratonic nuclei. These predominantly consist of multiphase grey gneisses 52 that comprise juvenile tonalite-trondhjemite-granodiorites (TTGs) and granitoids of various composition, depending on the exposed crustal level and pre-deformation history (e.g., Nutman et al. 53 1996; Moyen 2011; Anhaeusser 2014; Hoffmann and Kröner, in press). Associated with the granitoids 54 s.l. are greenstone belts, consisting of ultramafic, mafic and felsic volcanic rocks, and their plutonic 55

equivalents, as well as metasedimentary units. Often, only fragments of the original greenstone
associations of various sizes are interlayered with the grey gneisses.

58 Currently it is under debate in which tectonic environment the early continental crust on Earth formed and stabilized (e.g., van Kranendonk, et al., 2014; Hoffmann et al. 2016 and references 59 therein). Models invoke an initial phase of TTG formation, followed by reworking caused by collision 60 between crustal terranes and involvement of mantle-derived magmas by intrusion and underplating. 61 62 This led to formation of various types of granitoids that were subsequently strongly deformed and 63 migmatized during post-magmatic metamorphic events. The most prominent relicts of early crustal terranes are the Acasta Gneiss Complex, the Nuvvuagittuq region, the Hudson Bay terrane, and the 64 65 Eoarchean Labrador gneiss terranes of Canada, as well as the Itsaq Gneiss Complex of southern West Greenland, the Pilbara and northwestern Yilgarn Cratons of Australia, and the Ancient Gneiss 66 Complex located in the eastern Kaapvaal Craton of southern Africa (e.g., Bennett et al. 2007; Van 67 Kranendonk et al. 2007; Roth et al. 2013, 2014a; Kröner et al. 2014; O'Neil and Carlson 2017; and 68 references therein). 69

70 One key observation concerning early crust formation is the lack of Hadean (pre-4.0 Ga) crust in Archean terranes, raising the question whether such a protocrust was involved in the formation of 71 72 Archean terranes or not (e.g., Kemp et al. 2010; Zeh et al. 2011; O'Neil et al. 2013; O'Neil and 73 Carlson 2017). However, the Hadean age of ~4.3 Ga proposed for the Ujaraaluk unit in the 74 Nuvvuagittug greenstone belt suggests that portions of protocrust survived since its formation (O'Neil et al. 2008). Moreover, based on Hf isotope compositions in zircons, reworking of a Hadean or 75 76 Eoarchean protocrust has been proposed for different terranes (e.g., Iizuka et al. 2007; Kemp et al. 77 2010; Zeh et al. 2011; Kröner et al. 2014).

A powerful tool to test the involvement of Hadean crustal sources in the formation of Archean cratonic crust is the short-lived ¹⁴⁶Sm-¹⁴²Nd ($T_{1/2} = 103$ Ma ± 5 Ma, Meissner et al. 1987) decay system. Due to its short half-life, the ¹⁴⁶Sm-¹⁴²Nd decay system was only active in the first ca. 500 million years of Earth's evolution. Consequently, differentiation of crustal material from a mantle or crustal source before the extinction of ¹⁴⁶Sm will fractionate Sm and Nd because of the slightly more incompatible behavior of Nd compared to Sm during mantle and crustal melting, resulting in

heterogeneities in the ¹⁴²Nd/¹⁴⁴Nd composition of early differentiated terrestrial reservoirs (e.g., Harper 84 and Jacobsen 1992; Boyet et al. 2005; Caro et al. 2006; Rizo et al. 2012). During early crust-mantle 85 86 differentiation, the continental crust developed towards low Sm/Nd isotope ratios, expressed as negative μ^{142} Nd (μ^{142} Nd = (142 Nd/ 144 Nd_{sample} / 142 Nd/ 144 Nd_{standard} - 1) x 10⁶ in ppm) and the depleted 87 mantle developed with a high Sm/Nd isotope ratio, resulting in positive μ^{142} Nd values. Hence, an 88 offset in μ^{142} Nd relative to younger rocks can be ascribed to early terrestrial fractionation. Such early 89 90 terrestrial fractionation events may have included early magma ocean fractionation involving deep mantle phases such as bridgmanite and Ca-perovskite (Corgne et al. 2005) that would directly imprint 91 on the ¹⁴²Nd composition of the mantle, leaving behind early ¹⁴²Nd enriched and depleted reservoirs 92 93 (Boyet et al. 2005; Boyet and Carlson 2006; Caro et al. 2005, 2006). Furthermore, the formation of Hadean mafic crust and residual mantle is mirrored by the ¹⁴²Nd signature of Archean rocks (O'Neil et 94 95 al. 2008).

So far, all terrestrial rocks younger than 2.70 Ga were found to have a uniform ¹⁴²Nd/¹⁴⁴Nd isotopic composition with μ^{142} Nd of approximately 0 ± 5 ppm (e.g. Boyet and Carlson 2006; Caro et al. 2006; Roth et al. 2014b). In contrast, some ancient terrains show both positive and negative derivations in μ^{142} Nd compared to the terrestrial average value for post-Archean rocks.

Positive μ^{142} Nd anomalies relative to the terrestrial standard have been reported for rocks of 100 101 the early crustal terranes of Greenland, yielding maximum values of up to +20 ppm (e.g., Boyet and Carlson 2006; Caro et al. 2006; Bennett et al. 2007; Rizo et al. 2011, 2012, 2013; O'Neil et al. 2016). 102 These μ^{142} Nd anomalies were interpreted to directly trace a Hadean mantle reservoir that differentiated 103 between 4.32 Gyr and 4.51 Gyr ago. Complementary reservoirs with negative μ^{142} Nd were reported 104 105 from the Hadean/Eoarchean Nuvvuagittug Supracrustal Belt (-18 to +8 ppm; O'Neil et al. 2008, 2012; 106 Roth et al. 2013), the 3.40-3.75 Ga Ukalik belt and Innuksuac complex, Canada (-9 to +1 ppm; Caro et al. 2017), the Acasta gneisses, Canada (μ^{142} Nd as low as -16 ppm; Roth et al. 2014a), as well as from 107 108 the 3.4-3.5 Ga Ameralik dykes, Greenland (-11 to +16 ppm; Rizo et al. 2012). Similarly, komatiites from the ca. 3.55 Ga Schapenburg Greenstone Remnant (South Africa, Kaapvaal Craton) vielded 109 negative μ^{142} Nd anomalies as low as -13 ppm and were interpreted to trace material from the 110 111 crystallization of an early Hadean magma ocean (Puchtel et al. 2016).

Due to the short half-life of the ¹⁴⁶Sm-¹⁴²Nd isotope system, it can be used as a tool for tracing 112 early recycling and mantle stirring processes (Bennett et al. 2007). It has been recognized, that early 113 114 signatures virtually disappear in magmatic rocks throughout the Archean, with one exception from 2.7 Ga komatiites of the Abitibi belt (Canada) that yielded a μ^{142} Nd anomaly of up to +9 (Debaille et al. 115 2013). Recently, O'Neil and Carlson (2017) obtained negative μ^{142} Nd anomalies for ca. 2.75 Ga 116 granitoids from the Hudson Bay terrane (Canada), which indicate late Archean reworking of rocks 117 with negative μ^{142} Nd signatures that were derived from ancient reservoirs which initially differentiated 118 from the mantle in the Hadean. 119

120 In this study, we focus on Archean granitoids and mantle-derived rocks from the eastern Kaapvaal Craton (South Africa and Swaziland). We report the first high-precision ¹⁴²Nd/¹⁴⁴Nd 121 analyses for well-characterized granitoids and meta-tholeiites (amphibolites) of the Ancient Gneiss 122 Complex (AGC; Swaziland) and from the lower Onverwacht Group of the Barberton Greenstone Belt 123 (BGB; South Africa). The investigated samples span an age range from 3.66 Ga to 3.22 Ga and 124 125 represent the main lithological units of the AGC and the oldest rocks of the BGB. The data are used to 126 elucidate the differentiation and reworking history of the oldest part of the Kaapvaal Craton. The combination of data derived from the short-lived ¹⁴⁶Sm-¹⁴²Nd system with existing geological, 127 petrological and geochemical information for these samples lead to a deeper understanding of if and 128 129 how Hadean crustal components were incorporated into the sources of Archean crustal rocks, enabling 130 us to place general constraints on geodynamic processes operating in the early Archean.

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132 2. Geology of the Ancient Gneiss Complex and Barberton Greenstone Belt

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The 3.66-3.20 Ga AGC (Hoffmann and Kröner, in press, and references therein) is located in the eastern Kaapvaal Craton and predominantly comprises complexly deformed Paleo- to Mesoarchean grey gneisses of the TTG suite that are interlayered with rare amphibolites (Fig. 1; Hoffmann and Kröner, in press). The 3.66-3.45 Ga Ngwane Gneiss is the oldest component of the AGC (Hoffmann and Kröner, in press, and references therein) and is exposed in central and western Swaziland as well as in the Phophonyane Inlier of northwestern Swaziland. The Ngwane Gneiss 140 underwent ductile amphibolite- to granulite-facies metamorphism (Kröner et al. 1993, 2014 and 141 references theirein). The interlayered amphibolites represent mafic dykes (Jackson 1984; Hoffmann 142 and Kröner, in press) as well as infolded greenstone remnants (e.g., Jackson 1984; Kröner and Tegtmeyer 1994). The Ngwane Gneiss is intruded by the 3.478-3.430 Ga homogeneous and variously 143 foliated dioritic to tonalitic Tsawela Gneiss (e.g., Jackson 1984; Kröner et al. 1993; Hoffmann et al. 144 145 2016), granitoid gneisses of the ca. 3.23 Ga Usutu Intrusive Suite (Schoene et al. 2009), and the 3.1 Ga 146 Pigg's Peak batholith (Murphy 2015) which divides the AGC from the BGB in the north, as well as several other smaller plutons with ages up to 2.7 Ga (e.g., Zeh et al. 2011). The most prominent and 147 148 largest supracrustal succession within the AGC is the ca. 3.45 Ga Dwalile Greenstone Remnant (DGR; Kröner and Tegtmeyer 1994) exposed west of Mankanyane town along the border with South Africa. 149

To the northwest the AGC is tectonically separated from the 3.53-3.20 Ga BGB and surrounding plutons (e.g., Kröner et al. 1991, 1996; Van Kranendonk et al. 2009) by a major faulted contact, the Phophonyane shear zone (Fig. 1). The oldest unit of the BGB is the Onverwacht Group, which comprises mafic and ultramafic volcanic rocks that are interlayered with subordinate felsic volcanic rocks. The BGB is surrounded by several plutons, namely the Steynsdorp, Theespruit, Stolzburg, Nelshoogte, and Kaap Valley plutons with ages of ca. 3.51 to 3.20 Ga. Their compositions range from tonalite to trondhjemite (e.g., Anhaeusser 2014).

157 The AGC and the southern BGB are characterized by regionally extensive medium-pressure 158 and high-temperature metamorphism that occurred at ca. 3.2 Ga (e.g., Dziggel et al. 2005; Taylor et al. 159 2012). This metamorphic event led to lower granulite-facies ductile deformation, migmatization, and 160 anatexis, followed by syntectonic emplacement of granitoids in the lower and mid-crustal domains represented by the AGC (e.g., Schoene et al. 2008). In the BGB, this metamorphism caused a 161 162 greenschist- and upper amphibolite facies overprint, coupled with refolding and structural parallelism 163 between granitoid gneisses and supracrustal rocks (e.g., De Ronde and De Wit 1994; Lowe and Byerly 164 1999; van Kranendonk et al. 2009, 2014; Kröner et al., 2016).

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166 **3.** Samples and analytical techniques

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170 The strategy of our sample selection was to cover a comprehensive range of rocks representative of the early Archean crust of the AGC and BGB that included different lithological 171 units and ages, to gain structural and temporal resolution of possible changes in ¹⁴²Nd/¹⁴⁴Nd isotopic 172 compositions. We selected six well-characterized and least altered granitoid gneisses from the AGC, 173 174 including TTG compositions and grey gneisses of various origins, covering an age range from 3.66 Ga (grey gneiss AGC 150b; Kröner et al. 2014) to 3.22 Ga (grey gneiss AGC 445; age: personal 175 176 communication A. Kröner 2017). Three of these samples, the 3.66 Ga Ngwane grey gneiss (AGC 150b), the 3.55 Ga tonalite from north of Pigg's Peak town (AGC 370), and the 3.48 Ga tonalitic 177 178 Tsawela gneiss from west-central Swaziland (AGC 75), reveal heterogeneous Hf-in-zircon isotope 179 compositions implying involvement of older crustal components in the formation of these rocks (Kröner et al. 2014; Hoffmann et al. 2016). Additionally, the 3.26 Ga granodiorite from the Usutu 180 181 Suite (AGC 368) contains inherited zircons that date back to 3.45 Ga which is in agreement with 182 contribution from an older crustal source (ages: personal communication A. Kröner 2017). Furthermore, two amphibolites and one metagabbro from the AGC were selected, all dating back to 183 ages between >3.40 Ga (AGC 222; Kröner et al. 1993; Taylor et al. 2012; Suhr et al. 2015) and 3.46 184 185 Ga (AGC 45; Kröner & Tegtmeyer 1994; AGC 350 dated to 3.46 Ga; personal communication A. 186 Kröner 2016). In addition, we selected two ca. 3.45 Ga ultramafic rocks from the Dwalile Greenstone Remnant (Kröner and Tegtmeyer 1994) and one 3.24 Ga trondhjemitic gneiss which intruded into the 187 188 grey gneisses structurally below the Dwalile Greenstone Remnant (age: personal communication A. Kröner 2017). The latter sample contains inherited zircon grains of 3.49 Ga and ca. 3.64 Ga (ages: 189 190 personal communication A. Kröner 2017).

Rock types of the oldest supracrustal sequences of the BGB include one meta-tholeiite of the
Sandspruit Formation (KS-BA 189; supplementary material S1) and two samples of the Theespruit
Formation (meta-tholeiite BA 156, supplementary material S1; felsic metavolcanic rock AGC 372,
Kröner et al. 2013) as well as one meta-tholeiite of the Komati Formation (ZA-32a, supplementary
material S1). These samples span a narrower age range than the AGC granitoids from ca. 3.55 Ga to

196 3.48 Ga and are representative of the lower Onverwacht Group. In addition, μ^{142} Nd analyses were 197 conducted on a 3.46 Ga tonalite component of the Theespruit Pluton, containing heterogeneous Hf-in-198 zircon isotopic compositions (e.g. sample BA 115 from Kröner et al. 2016 that was taken at the same 199 locality), and a 3.51 Ga sample of the Steynsdorp Pluton. More detailed descriptions are provided in 190 Kröner & Tegtmeyer (1994), Kröner et al. (2013, 2014, 2016), and Hoffmann et al. (2016). Sample 201 localities are shown in Figure 1.

- 202
- 203 3.2 Analytical methods
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The chemical separation for Nd isotopes is described in detail in the supplementary material 205 S2. Neodymium isotope measurements were performed using a Thermo-ScientificTM Triton multi-206 collector thermal ionization mass spectrometer (MC-TIMS) at the Laboratoire Magmas et Volcans 207 208 (LMV), University Clermont Auvergne, Clermont Ferrand, France. Neodymium fractions were dissolved in 2 µl of 2.5 N HCl and loaded onto outgassed zone-refined Re filaments. Neodymium was 209 210 measured as Nd⁺ using a second bare Re filament as ionization filament. Each measurement was 211 performed in 27 blocks of 20 cycles each (~8 s integration) in dynamic mode using amplifier rotation. The background was measured before each block. After a series of 9 blocks, readjustment of the focus 212 and a peak center were conducted. For the dynamic mode, one line of measurements was performed 213 with the mass ¹⁴⁵Nd in the central faraday cup with ¹⁴⁰Ce being monitored in the L4 and ¹⁴⁷Sm in the 214 H2 faraday cup. The second line was measured with the mass ¹⁴³Nd in the central faraday cup, 215 monitoring ¹³⁸Ba in the L4 faraday cup to check if the ionization of Nd isotopes was not hampered due 216 to a high Ba signal. If possible, samples were run repeatedly up to three times on the same filament, 217 218 depending on the Nd content (notation #R1, #R2, and #R3 in Table 1, respectively).

Roth et al. (2014b) showed that rapid sample fractionation between the sequential measurement of ¹⁴⁶Nd/¹⁴⁴Nd and ¹⁴²Nd/¹⁴⁴Nd (2 lines acquisition) can induce large biases on dynamic ¹⁴²Nd/¹⁴⁴Nd ratios. The fractionation rates calculated for samples and standards during this study are on average 0.215 ppm.s⁻¹ and 0.175 ppm.s⁻¹, respectively. These values are far below the threshold limit of 0.4 ppm.s⁻¹. A fractionation rate that would produce a bias on dynamic ¹⁴²Nd/¹⁴⁴Nd ratios must
be higher than 5 ppm.

225 Neodymium isotope ratios were corrected for mass fractionation using the exponential law and 146 Nd/ 144 Nd = 0.7219. Data are reported relative to the JNdi-1 standard which was measured along 226 with the samples, resulting in an average long-term 142 Nd/ 144 Nd ratio of 1.141839 ± 4.4 ppm (2s.d., n = 227 13) for the first analytical session (LMV Triton) and 1.141827 ± 4.3 ppm (2s.d., n = 17) for the second 228 229 session (LMV Triton Plus), if the analyses would follow a normal distribution. However, given a relatively limited number of JNdi-1 analyses within the two analytical sessions, i.e. 13 and 17 times, a 230 student's t distribution for calculating the 95% confidence interval would be more appropriate. With 231 this calculation, the deviations from the mean ¹⁴²Nd/¹⁴⁴Nd ratio for the first and second standard 232 analytical sessions result in \pm 1.33 ppm and \pm 1.10 ppm, respectively. 233

Available major and trace element as well as ¹⁴⁷Sm-¹⁴³Nd and ¹⁷⁶Lu-¹⁷⁶Hf isotope data for all samples are summarized in Table S1 of the supplementary material. A summary of the analytical methods for samples AGC 222, AGC 350, AGC 445, AGC 473, BA 132, BA 156, KS-BA 189, and ZA-32a is provided in the supplementary material S3.

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240 **4. Results**

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Table 1 summarizes the results for ¹⁴²Nd/¹⁴⁴Nd, ¹⁴³Nd/¹⁴⁴Nd, ¹⁴⁵Nd/¹⁴⁴Nd, ¹⁴⁶Nd/¹⁴⁴Nd, 242 ¹⁴⁸Nd/¹⁴⁴Nd, and ¹⁵⁰Nd/¹⁴⁴Nd measurements on seventeen samples from the BGB and AGC, 243 respectively. The Hawaiian basalt BHVO-2 was measured as reference material, and the data as well 244 245 as repeated analyses of the terrestrial standard JNdi-1 are listed in Table 1. Measurements have been 246 performed during two different analytical sessions and using the two LMV thermal ionization mass spectrometers: Triton[™] (session 1) and Triton Plus[™] (session 2). The BHVO-2 standard yielded a 247 μ^{142} Nd of 2.4 ± 4.4 ppm, overlapping within error with the JNdi-1 terrestrial standard measured in 248 session 1. The analytical uncertainties on ¹⁴²Nd/¹⁴⁴Nd for single internal sample runs were usually 249 250 better than 3.9 ppm, except for two samples (AGC 350, KS-BA 189), which had internal

251	reproducibilities between ± 4.0 ppm and ± 5.0 ppm (Table 1). However, in the figures we report the
252	2s.d. external reproducibility from the standard sessions for samples that were only measured once.
253	For repeated measurements $(n = 2-3)$ a mean value was calculated and is also reported together with
254	the 2s.d. of the standard sessions, because the external reproducibility of the standard is better
255	constrained than those of the sample analyses.

Measured μ^{142} Nd values in samples of the Kaapvaal Craton range from -7.9 ± 4.4 ppm to +3.0 ± 4.3 ppm (Fig. 2). Confidently resolvable μ^{142} Nd anomalies were found in a 3.44 Ga Ngwane Gneiss (AGC 352) and two ca. 3.45 Ga (ultra-)mafic rocks from the Dwalile Supracrustal Suite (AGC 45 and 50), having μ^{142} Nd values of -7.9 ± 4.4 ppm ,-6.2 ± 4.3 ppm, and -6.1 ± 4.3 ppm, respectively.

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261 5. Discussion

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263 5.1 Evaluation of metamorphic disturbance

All samples from the AGC and BGB underwent metamorphic overprint up to amphibolitefacies conditions. Such metamorphic events could cause element migration and, hence, disturbance of the Nd isotope compositions by metamorphic fluids. However, our samples do not show any correlation of their μ^{142} Nd signatures with, for example, enrichment in light rare earth or large ion lithophile elements (Figure S4 of the supplementary material). Consequently, we consider the μ^{142} Nd anomalies in the AGC and BGB rocks as reflecting original source compositions.

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5.2 Significance of negative ¹⁴²Nd signatures in Archean rocks of the Ancient Gneiss Complex

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The first μ^{142} Nd data reported for the AGC provide evidence for the preservation of a negative μ^{142} Nd isotope signature throughout different lithological units of the AGC (Fig. 2). However, only three samples can be readily distinguished in terms of μ^{142} Nd compared to the modern terrestrial reference material. Nevertheless, as shown in Figure 3a, all of our analyzed samples from the BGB and AGC taken together as one population show a statistically significant offset from the standard towards negative μ^{142} Nd values. Furthermore, as illustrated in Figure 3b, a bimodal distribution can be

observed with one population of ten samples having generally negative μ^{142} Nd anomalies with an 279 average of -5.3 ± 1.0 ppm (95% conf. int.) relative to the terrestrial standard and another population of 280 seven samples showing no deviation from the JNdi-1 terrestrial standard with a mean μ^{142} Nd of 0.4 ± 281 1.2 ppm (95% conf.int.). The presence of negative μ^{142} Nd values requires the involvement of an older 282 crustal or enriched mantle reservoir in their petrogenesis. This could have occurred either by direct 283 melting of a Hadean enriched protocrust that remained unaffected by melting or crustal recycling since 284 285 its differentiation (e.g., O'Neil et al. 2008; O'Neil and Carlson 2017) or by inheritance of a Hadean μ^{142} Nd signature from older granitoids that formed after the extinction of ¹⁴⁶Sm and were contaminated 286 by Hadean crustal material, ultimately resulting from Hadean mantle-derived mafic melts. 287 Alternatively, the negative μ^{142} Nd anomalies were inherited from the mantle source that underwent a 288 289 differentiation event in the Hadean accompanied by a decrease of Sm/Nd and may have interacted with the early cratonic nuclei to produce granitoids with variably negative μ^{142} Nd values. 290

Preserved Archean continental crust is interpreted to consist, to large degrees, of juvenile 291 292 TTGs, which represent direct melts of metamorphosed mafic crust (e.g., Moyen and Martin 2012 and 293 refs. therein). However, many Archean crustal terranes are now composites of grey gneisses that have 294 diverse origins and complex formation histories involving crustal reworking processes (e.g., Moyen 295 2011; Hoffmann et al. 2011). Here, interaction of mantle-derived magmas with older felsic crust may 296 have been common, leading to further differentiation and diversification of the Archean crust and, ultimately, to stabilization of the crust (e.g., Laurent et al. 2014; Hoffmann et al. 2016). This is the 297 298 case for the early Archean crust of the eastern Kaapvaal craton where, on the basis of heterogeneous Hf isotope signatures of zircons from grey gneiss samples, different studies argued for interaction of 299 300 juvenile mantle-derived magmas with older felsic crust (Zeh et al. 2011; Kröner et al. 2014; Hoffmann 301 et al. 2016) or melting of older felsic crust in the presence of zircon (e.g., Tang et al. 2014). Moreover, 302 rare inherited Eoarchean zircon grains were found in rocks of the AGC (e.g., Kröner and Tegtmeyer 303 1994), thus providing additional support for the involvement of older crustal rocks in the genesis of 304 the exposed crust. Interestingly, depleted mantle Lu-Hf model ages for zircons from the Ngwane 305 gneisses were calculated to be up to 4.1 Ga (e.g., Zeh et al. 2011; Kröner et al. 2014). However, the 306 complex intra-crustal differentiation processes make one-stage model ages unlikely, and the calculated ages would only provide minimum ages for the initial extraction of melt from a hypothetical depletedmantle reservoir.

309 Juvenile crustal additions to the AGC were largely restricted to the mid-Paleoarchean (e.g., Zeh et al. 2011; Kröner et al. 2014; Hoffmann et al. 2016). The granitoids measured here for their 310 ¹⁴²Nd/¹⁴⁴Nd isotope compositions cover an age range from ca. 3.66 to ca. 3.22 Ga. The only clearly 311 resolvable negative ¹⁴²Nd anomaly was found in a 3.44 Ga Ngwane grey gneiss from the Mankanyane 312 313 region. In this sample, the zircon Hf isotope compositions were heterogeneous (Hoffmann et al. 2016), in support of the conclusions of Kröner et al. (2014) and Hoffmann et al. (2016) that these rocks 314 formed by melting of older crustal material. The negative μ^{142} Nd value, however not resolvable from 315 the terrestrial standard, in the youngest 3216 Ma grey gneiss investigated in this study indicates that 316 317 back-mixing of crustal components into the mantle or, alternatively, mantle reservoirs carrying the ¹⁴²Nd anomaly lasted at least until 3.2 Ga, and this process can potentially be traced in various 318 319 granitoids of different ages.

Except for two samples of the Dwalile Greenstone Remnant (AGC 45, 50) that bear resolvable 320 negative µ¹⁴²Nd anomalies, two other Palaeoarchean amphibolites (AGC 222; AGC 350) from Kubuta 321 322 in central Swaziland and the Mtimane River NE of Mankayane do not show any discernable offset from the modern terrestrial μ^{142} Nd value (Fig. 2). These two amphibolites without anomalies may 323 324 constitute end members during complex crustal assimilation and mixing processes, involving melts 325 derived from older Ngwane gneiss basement as suggested by Hoffmann et al. (2016) for the 3.48-3.43 Ga Tsawela gneiss suite. Hence, the most negative μ^{142} Nd values in the Ngwane and Tsawela gneisses 326 may still represent intermediate values, providing that the two modern-like amphibolites measured in 327 this study are indeed representatives of juvenile mafic melts. Unfortunately, these two amphibolites 328 are infolded in the Ngwane gneiss, and intrusive relationships between the two components are not 329 330 preserved at these localities.

For the Dwalile Greenstone Remnant, Kröner and Tegtmeyer (1994) reported initial ε^{143} Nd data for amphibolites, hornblende-schists, and metasediments ranging from positive to negative ε^{143} Nd_(t) values that are in agreement with variable degrees of crustal contamination as well as incorporation of older crustal detritus in sedimentary rocks of the belt. Moreover, inherited zircon

grains, up to 3.7 Ga in age, were reported in the gneissic basement structurally below the Dwalile 335 Geenstone Remnant (Kröner and Tegtmeyer 1994), indicating an older felsic crustal basement. So far, 336 337 there are no detailed studies on the geochemical composition of the AGC mafic rocks, but crustal 338 contamination of our two amphibolite samples from Dwalile can at least be excluded, on the basis of 339 flat trace element patterns and depleted to chondritic Hf-Nd isotopic compositions. The observed 340 negative μ^{142} Nd anomalies of Dwalile samples AGC 45 and AGC 50 may thus be representative of the tapped mantle source. Interestingly, enriched (i.e., negative) μ^{142} Nd and μ^{182} W deviations have been 341 reported for komatiites of the 3.55 Ga Schapenburg Greenstone remnant ca. 65 km away (Puchtel et al. 342 2016). These signatures were interpreted by the authors as being of mantle origin, likely related to 343 fractionation processes involving Ca-Mg perovskite in an early magma ocean. Decoupling of ¹⁴²Nd 344 and ¹⁴³Nd systematics with mean negative μ^{142} Nd (μ^{142} Nd = -5 ± 2.8 ppm) and positive ϵ^{143} Nd (ϵ^{143} Nd 345 = $+2.4 \pm 0.1$) in Schapenburg komatiites was interpreted to reflect a melt depletion event within the 346 komatiite source at the end of the lifetime of ¹⁴⁶Sm at ca. 4027 Ma. Hence, both the mafic precursor 347 rocks of AGC crust and the mantle-derived rocks in the Schapenburg area may have tapped the same 348 349 mantle reservoirs.

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351 5.3 Relation between the Ancient Gneiss Complex and the Barberton Greenstone Belt

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353 The AGC is tectonically separated from the supracrustal BGB by the Phoponyane shear zone 354 northwest of Pigg's Peak town, possibly indicating that the two terranes were originally separated and amalgamated at around 3.3 to 3.2 Gyr (De Ronde and De Wit, 1994) or 3.55 to 3.42 Gyr ago (Kröner 355 356 et al., 1996), respectively. In contrast to the AGC, the majority of rock units of the BGB terrane, 357 namely the 3.55 Ga to 3.53 Ga amphibolites of the lowermost Onverwacht Group as well as the 3.51 Ga Steynsdorp and 3.46 Ga Theespruit plutons, do not show any deviation in μ^{142} Nd from the 358 359 terrestrial standard (Fig. 2). Hence, these units have not inherited a Hadean crustal or mantle reservoir that differentiated during the lifetime of ¹⁴⁶Sm. However, two samples of the lower Onverwacht 360 Group, a 3.55 Ga felsic volcanic rock (AGC 372; Theespuit Fm.) and a 3.48 Ga meta-tholeiite (ZA-361 32a; Komati Fm.) show a tendency towards negative μ^{142} Nd anomalies (Fig. 2) that are not fully 362

resolvable from the JNdi-1 terrestrial standard. Yet, we consider these features as being important forthe interpretation of the geodynamic setting in which the BGB formed.

365 Kröner et al. (2013, 2016) proposed that the felsic metavolcanic rocks of the lower Onverwacht Group originated from interaction of an older crustal source with juvenile, underplated 366 material. These authors based their conclusions on heterogeneous Hf isotope compositions in zircons 367 and calculated crustal model ages for the precursor ranging from 3.60 to 3.95 Ga. However, the 368 negative μ^{142} Nd signature (μ^{142} Nd = -5.6 ± 4.4 ppm) of the felsic volcanic rock (AGC 372) 369 investigated in this study is not very pronounced, and it is likely that the ca. 3.60 to 3.95 Ga precursors 370 only carried a diluted Hadean isotope signature because they formed after the lifetime of ¹⁴⁶Sm. Such a 371 372 model would be in agreement with the contribution of AGC-like basement beneath the lower 373 Onverwacht Group as a source for felsic volcanism within the BGB. This hypothesis is also supported by ca. 3.7 Ga inherited zircon grains reported from Theespruit felsic volcanic rocks (Roerdink et al. 374 2016) and from the adjacent 3.2 Ga Vlakplaats pluton (Kröner et al. 1996). Therefore, it is likely that 375 376 felsic volcanic rocks of the BGB were initially fed by magma chambers that are elsewhere represented by second generation granitoids such as the Tsawela gneiss suite that carry a diluted Hadean μ^{142} Nd 377 signature, as they are exposed at crustal levels of the AGC (Hoffmann et al. 2016). 378

Another interesting observation of this study is the tendency towards negative μ^{142} Nd in the 379 younger meta-tholeiite sample of the ca. 3.48 Ga Komati Formation (sample ZA 32a) with a μ^{142} Nd 380 value of -5.4 ± 4.3 ppm (Fig. 2). Previous studies focused exclusively on komatiites from the 381 Barberton type locality and from the 3.26 Ga Weltevreden Fm. that do not preserve any resolvable 382 μ^{142} Nd deviation (Caro et al. 2006; Puchtel et al. 2016). Yet, initial ϵ^{176} Hf and initial ϵ^{143} Nd 383 compositions for rocks from the Komati Fm. are predominantly positive, showing no evidence of 384 385 contamination by older crust (Blichert-Toft and Arndt 1999; Blichert-Toft et al. 2015). In contrast, 386 trace element compositions of some spinifex-textured komatiites of the Komati Fm. were interpreted 387 to reflect contamination with older continental crust (Robin-Popieul et al. 2012). The flat trace element 388 pattern as well as the juvenile Hf-Nd isotope signature of meta-tholeiite ZA 32a (supplementary material S1) are not in agreement with crustal contamination. Hence, two different mantle reservoirs 389 may have been tapped by Komati Fm. magmas producing komatiites with modern-like μ^{142} Nd on the 390

one side and tholeiites with negative μ^{142} Nd on the other side, possibly reflecting mixing between ascending mantle plume magmas and ambient upper mantle or lithospheric mantle (e.g., Sossi et al. 2016, and references therein) that bear a small ¹⁴²Nd deficit.

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395 5.4 Origin of the negative μ^{142} Nd signatures in rocks of the AGC and BGB

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In Figure 3b, the samples investigated in this study plot in a bimodal distribution. One trend comprises seven samples with no μ^{142} Nd anomalies and the other trend includes ten samples having a tendency to negative μ^{142} Nd signatures. The trends may reflect two separate mantle reservoirs. Interestingly, both reservoirs must have been tapped concurrently, independent of magmatic age and lithological unit. Collectively, both μ^{142} Nd reservoirs are represented by samples spanning an age range from 3.66 Ga to 3.23 Ga (for the μ^{142} Nd = +0.4 reservoir) and 3.55 Ga to 3.22 Ga (for the negative μ^{142} Nd reservoir). Notably, both reservoirs are represented by samples of the AGC and BGB.

The enriched end member, as represented by the Dwalile amphibolites, was therefore mantle-404 405 derived and interacted with differentiated AGC crust. Since some (ultra-)mafic Dwalile rocks were 406 potentially crustally contaminated (e.g., Kröner and Tegtmeyer 1994) the measured value may thus not represent the true negative μ^{142} Nd value of the enriched reservoir, provided that the contaminating 407 crust had positive or modern-like μ^{142} Nd. The original values for this reservoir may be represented by 408 the mantle source tapped by the 3.55 Ga Schapenburg komatiites, which yielded negative μ^{142} Nd 409 410 values as low as -13.4 ppm compared to the terrestrial standard (Puchtel et al. 2016; Fig. 3c). This may indicate that the negative μ^{142} Nd values of the Komati Fm. tholeiite and the Dwalile amphibolites as 411 well as some granitoids may represent intermediate values which already reflect mixing between 412 413 enriched and modern-like mantle reservoir end members. However, it is difficult to estimate the exact 414 mixing parameters and whether the two reservoirs were genetically related to each other.

For mantle derived rocks, the combined use of ¹⁴²Nd and ¹⁴³Nd isotope systematics can be applied as a tool for the calculation of model ages reflecting Hadean mantle differentiation events (e.g., Harper and Jacobsen 1992; Caro et al. 2006; Rizo et al. 2011). However, for granitoids with complex histories such as those of the AGC, this method is not applicable due to multiple 419 metamorphic resetting and mixing of the 147 Sm- 143 Nd system during crustal reworking, which occurred 420 after extinction of the 146 Sm- 142 Nd system, leading to decoupling of the two systems.

As the (ultra-)mafic samples from Dwalile and the tholeiite from Barberton seem to be derived from an enriched reservoir, it is likely that their mantle source already carried an enriched ¹⁴²Nd signature. Assuming that the (ultra-)mafic Dwalile rocks and the Komati Fm. tholeiite represent mantle source compositions, and provided that metamorphism did not disturb their ¹⁴⁷Sm/¹⁴⁴Nd, a minimum age for the differentiation of their mantle sources can be calculated (Figure 4). As shown in Figure 4, the mantle source from which the Dwalile komatiites and the Komati tholeiite were derived may have differentiated at 4.3 Gyr ago.

The ultimate origin of the negative μ^{142} Nd anomaly in the Dwalile komatiites and the Komati tholeiite may therefore be related to early magma ocean differentiation (e.g., Puchtel et al. 2016) or to recycling of enriched Hadean protocrust back into the mantle (Guitreau et al. 2012; Caro et al. 2017). However, it is not possible to confidently constrain which of these two possibilities is applicable to the AGC and BGB (ultra-)mafic rocks.

Constraining the origin of the enriched ¹⁴²Nd signature in the AGC granitoids is similarly 433 challenging. A direct contribution of enriched mafic Hadean protocrust to the TTG precursors of the 434 435 AGC, sporadically occurring over a time period of ca. 1 billion years, is likely. Such a process has recently been suggested for the Hudson Bay terrane by O'Neil and Carlson (2017). Alternatively, the 436 negative μ^{142} Nd anomalies in the granitoids could also be the result of repeated re-melting of granitoid 437 crust that inherits a negative μ^{142} Nd signature, ultimately derived from recycled enriched Hadean 438 protocrust, and mixing with mafic melts that formed after the extinction of ¹⁴⁶Sm. This hypothesis is 439 based on the fact that the Nd budget would be dominated by the crustal rocks during crustal 440 441 reworking. For example, the Dwalile mafic and ultramafic rocks have Nd contents of 5.56 and 8.19 ppm, respectively, whereas the Nd concentrations of the granitoids carrying the negative ¹⁴²Nd 442 signature range from 12.2 to 37.5 ppm (Table S1).Decoupling of enriched ¹⁴²Nd isotope signatures in 443 the AGC granitoids from the Hf isotope record as represented by zircons (Zeh et al. 2011; Kröner et al. 444 2014; Hoffmann et al. 2016), where a trend toward more radiogenic compositions with time can be 445 observed (Hoffmann and Kröner in press), would argue for the latter hypothesis. This decoupling is 446

independent of age or sample locality and confirms that both the enriched and modern-like reservoirscontributed to the formation of AGC rocks since at least the early Archean.

In summary, our study reveals that two mantle reservoirs were involved in the formation of the AGC and BGB rocks in the eastern Kaapvaal Craton that can be distinguished by means of their μ^{142} Nd signatures. The enriched ¹⁴²Nd reservoir likely has a minimum mantle differentiation age of 4.3 Ga (Fig. 4) and was incorporated into the (ultra-)mafic Dwalile and some Komati Fm. rocks since some 3.45 Gyr ago. In contrast, the modern-like reservoir is trapped in mafic AGC and BGB rocks ranging in age from 3.55 to ca. 3.40 Ga. It would appear that no mixing occurred between the two reservoirs throughout the Archean or that such mixing cannot be resolved within the analytical error.

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457 5.5 Worldwide sources of early enriched and depleted ¹⁴²Nd signatures through time

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Decreasing negative and positive Hadean μ^{142} Nd anomalies through time (Figure 5a,b) have 459 been interpreted to represent increasing homogenization of early differentiated reservoirs (e.g., Boyet 460 461 and Carlson 2005; Caro et al. 2006; Bennett et al. 2007; Rizo et al. 2012). However, it is ambiguous as to whether this homogenization of early-differentiated reservoirs is only seen in mantle-derived rocks 462 through time or also in the stabilized cratons. Figure 5a shows all published μ^{142} Nd data for rocks 463 directly derived from mantle melts, and Figure 5b depicts μ^{142} Nd data for felsic crustal rocks with ages 464 of ca. 4.3 to ca. 2.65 Ga. The compilation in Figure 5a indicates that enriched and depleted ¹⁴²Nd 465 466 mantle reservoirs were only partially homogenized by 2.65 Ga and that enriched and depleted sources were, in fact, tapped by mantle-derived rocks throughout the Archean. Felsic crustal rocks, however, 467 can preserve the anomaly over longer time scales than mafic-ultramafic rocks since they are reworked 468 from older rocks that share enriched or depleted ¹⁴²Nd signatures ultimately derived from stabilized 469 470 mafic precursors (e.g., Roth et al. 2014a; O'Neil and Carlson 2017). Alternatively, the signatures in 471 felsic rocks may indicate protocrustal material that was recycled back into the mantle (Guitreau et al. 2012; Caro et al. 2017). In the former case, enriched or depleted ¹⁴²Nd signatures are tapped directly 472 from a Hadean protocrust, whereas in the latter case the ¹⁴²Nd anomalies are traced by basaltic crust 473 474 that was formed by re-enriched mantle material. Our study on the eastern Kaapvaal Craton reveals that

ancient enriched mantle reservoirs were likely present until at least 3.45 Ga, as represented by the 475 Dwalile amphibolites, thus confirming earlier studies from Greenland (Rizo et al. 2012) and 476 Schapenburg (Puchtel et al. 2016), as well as Acasta where the most negative μ^{142} Nd values are found 477 in samples with low SiO₂ (Roth et al. 2014a). Further melting of such mafic material, as well as of 478 older felsic crust, incorporated negative μ^{142} Nd signatures in crustal rocks of the AGC until at least 479 3.22 Ga. This indicates that re-mixing of components containing inherited enriched ¹⁴²Nd crustal or 480 481 mantle reservoirs in the eastern Kaapvaal Craton lasted for more than 1 Gyr from the initial 482 differentiation events in the Hadean at ca. 4.3 Ga to the Mesoarchean at about 3.2 Ga.

Our study reveals that crustal nuclei may have tapped two completely separate mantle sources that were present throughout most of the Archean. Mixing between the two sources may have taken place, but is not reflected in our dataset (Fig. 5a,b). Nevertheless, the large range in complementary enriched and depleted ¹⁴²Nd isotope signatures in other Archean cratons such as in Canada or Greenland (Fig. 5a) possibly reflects multiple mantle reservoirs that may have mixed with each other instead of preserving single-stage processes, i.e., direct tapping of Hadean crustal or mantle material.

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490 6. Conclusions

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We report the first high-precision ¹⁴²Nd/¹⁴⁴Nd analyses for well characterized granitoids and 492 493 meta-tholeiites (amphibolites) of the Ancient Gneiss Complex (Swaziland) and the lower Onverwacht Group of the Barberton Greenstone Belt (South Africa). Our study reveals that representative well-494 preserved crustal and mantle-derived rocks of the AGC and BGB show variable μ^{142} Nd values ranging 495 from -7.9 \pm 4.4 ppm to +3.0 \pm 4.3 ppm. As reflected by their ¹⁴²Nd/¹⁴⁴Nd isotope compositions, two 496 497 different mantle reservoirs must have been involved in crust-forming processes between 3.66 and 3.22 Ga. The metamorphic rocks sampling the two reservoirs are indistinguishable in terms of age, 498 lithology or sample locality. Negative u¹⁴²Nd anomalies indicate the involvement of an early-enriched 499 mantle reservoir in the formation of the AGC that differentiated in the Hadean during the lifetime of 500 ¹⁴⁶Sm. This reservoir is likely entirely mantle-derived and was possibly reworked throughout the 501 Archean, yielding a 142 Nd/ 144 Nd model age of ca. 4.3 Ga. The presence of negative μ^{142} Nd anomalies 502

in mantle-derived rocks as late as 3.45 Ga confirms the presence of enriched ¹⁴²Nd reservoirs in the 503 504 Paleoarchean mantle. Reworking of crustal rocks may have transferred the enriched signature to granitoids of the AGC that are as young as 3.22 Ga. Parallel to AGC crust that was derived from 505 506 enriched mantle domains, other mantle-derived rocks and complementary granitoids of the AGC and 507 the BGB were derived from mantle domains that do not show evidence for early differentiation events 508 during the lifetime of ¹⁴⁶Sm. Our finding of enriched and modern-like mantle reservoirs by means of ¹⁴²Nd in the Kaapvaal Craton raises the question of whether other Archean cratons such as in West 509 Greenland, Canada or Western Australia underwent a similar complex reservoir mixing history instead 510 511 of single-stage processes. Such parallel behavior of enriched and depleted mantle and crustal domains 512 may have played a more pronounced role in the formation of Archean cratons around the world than previously thought. 513

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Figure 1: Simplified geological map of the Ancient Gneiss Complex (Swaziland) and Barberton
Greenstone Belt (South Africa) in the eastern Kaapvaal Craton. Red dots mark sample localities of the
investigated felsic, mafic, and ultramafic rocks. Map modified after Van Schijndel et al. (2017).



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Figure 2: Measured μ^{142} Nd values for the studied AGC and BGB rocks. Usually single measurements of granitoids (purple) and (ultra-)mafic rocks (green) are reported except for samples AGC 150b, AGC 75, AGC 350, AGC 50, BA 132, and BA 128 where single measurements are represented by lighter symbols and the mean values are represented by the dark filled symbols. Samples AGC 352, AGC 45,

and AGC 50 show resolvable negative anomalies relative to the terrestrial value (grey vertical box). Additionally, four samples (AGC 75, 372, 445, and ZA-23a) show a tendency to slightly negative μ^{142} Nd values that are, however, within error not unambiguously resolvable from the JNdi-1 terrestrial standard. The 95% confidence interval of the JNdi-1 standard was \pm 1.3 ppm for the first analytical session and \pm 1.1 ppm for the second analytical session (grey vertical box). Literature data for Barberton and Schapenburg komatiites is shown for comparison.

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Figure 3: Histograms of μ^{142} Nd data. A) Distribution of analyzed samples (black line with grey bars) 546 with an average μ^{142} Nd of -3.0 ± 1.6 ppm (95% conf.int.). Additionally, the average μ^{142} Nd of 0 ± 1.3 547 548 ppm (95% conf.int.) of the standard analyses is also shown (yellow line and yellow shaded area). A student's t-test of the two populations resulted in a probability $p_{Sa/St}$ of 0.002 (i.e. 0.2 %) that the two 549 populations belong to one group, i.e. the two groups are statistically significantly different. B) 550 Distribution of analyzed samples divided into a bimodal distribution with an enriched group having an 551 average μ^{142} Nd of -5.3 ± 1.0 ppm (95% conf.int., n = 10; purple line and shaded area) and a modern-552 553 like group averaging $+0.4 \pm 1.2$ ppm (95% conf.int., n = 7; blue line and shaded area). A student's t-

test of the two groups resulted in a probability $p_{EG/MG}$ of 4.8×10^{-7} (i.e. 0.000048 %) that the two 554 555 populations belong to one group, i.e. the two groups are statistically significantly different. C) 556 Comparison of our data to literature data of the Schapenburg komatiites (orange line and shaded area; Puchtel et al. 2016) and Barberton komatiites (green line and shaded area; Caro et al. 2006, Puchtel et 557 al. 2013). The Schapenburg komatiites have an average μ^{142} Nd of -5.0 ± 1.3 ppm (95% conf.int.) 558 resembling our enriched group of samples, and the Barberton komatiites have an average μ^{142} Nd of -559 0.7 ± 1.2 ppm (95% conf.int.) resembling our modern-like group of samples, which confirms our 560 interpretation of the involvement of two mantle sources in the formation of these rocks. 561





Figure 4: μ^{142} Nd vs. ¹⁴⁷Sm/¹⁴⁴Nd. The Dwalile komatiites and Komati Fm. tholeiite analyzed in this study yielded a mantle source differentiation age of ca. 4.3 Ga, provided that their ¹⁴⁷Sm/¹⁴⁴Nd ratio was not disturbed by secondary alteration. However, given the sample uncertainties, the source

differentiation age could vary between 4.1 and 4.4 Ga. The granitoids showing negative μ^{142} Nd 567 signatures inherited a contribution from the enriched mantle reservoir. Another group of granitoids and 568 mafic rocks of the AGC and BGB did not tap the enriched mantle reservoir. The dark grey square 569 represents the chondritic Sm/Nd ratio of 0.196. The light grey box represents the 95% confidence 570 interval of 1.3 ppm obtained for measurements of the JNdi-1 terrestrial standard. The figure is 571 572 modified after O'Neil and Carlson (2017), who calculated reference isochrones for 4.4-, 4.3-, and 4.2billion years old crustal reservoirs that were derived from a mantle with a chondritic Sm/Nd ratio. 573 574 Literature data are from Caro et al. (2006), Puchtel et al. (2013, 2016).



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Figure 5: Compilation of published μ^{142} Nd data against age for Archean cratons worldwide, including literature and our data for the Kaapvaal Craton. A) Mantle-derived rocks against age. B) Granitoid rocks against age. The compiled μ^{142} Nd anomalies for mantle-derived rocks indicate re-mixing of reservoirs with positive and negative μ^{142} Nd signatures with time. A similar trend is overserved for the granitoids, but the mechanism may be different for different tectonic environments (see text). The age of mafic Nuvvuagittuq rocks is currently under debate. References: Boyet and Carlson 2006; Caro et al. 2006, 2017; Bennett et al. 2007; O`Neil et al. 2008, 2012, 2016; Rizo et al. 2011, 2012, 2013;

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| Sample | Age | ¹⁴² Nd/ ¹⁴⁴ Nd

 | ±2s.e. on last
decimals place | µ ¹⁴² Nd (ppm) | ±2s.e. (ppm) | ¹⁴³ Nd/ ¹⁴⁴ Nd | ±2s.e. on last
decimals place
| ε143Nd* | ¹⁴⁵ Nd/ ¹⁴⁴ Nd | ±2s.e. on last
decimals place | µ ¹⁴⁵ Nd (ppm) | ±2s.e. (ppm) | ¹⁴⁶ Nd/ ¹⁴⁴ Nd
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decimals place | ¹⁴⁸ Nd/ ¹⁴⁴ Nd | ±2s.e. on last
decimals place | µ ¹⁴⁸ Nd (ppm) | ±2s.e. (ppm)
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 | 4 | -5.6 | 3.7 | 0.510649 | 2
 | -0.6 | 0.348406 | 1 | 12.6 | 3.4 | 0.722331
 | 100 | 0.241581 | 2 | -7.5
 | 6.2 | 0.236448 | 2 | -35.7 | 7.9 |
| BA156 | 3530 | 1.141839

 | 4 | 0.0 | 3.2 | 0.512711 | 2
 | 0.8 | 0.348404 | 1 | 7.0 | 2.8 | 0.723225
 | 60 | 0.241581 | 1 | -5.8
 | 5.0 | 0.236450 | 2 | -26.4 | 7.2 |
| AGC75 #R1 | 3478 | 1 141833

 | 4 | -4.8 | 3.9 | 0 510531 | 2
 | | 0 348403 | 1 | 2.8 | 37 | 0 721429
 | 24 | 0 241580 | 1 | -13.0
 | 6.0 | 0 236449 | 2 | -30.0 | 81 |
| AGC75 #R2 | 3478 | 1.141832

 | 4 | -5.9 | 3.7 | 0.510532 | 2
 | | 0.348402 | 1 | 0.7 | 3.3 | 0.722741
 | 53 | 0.241580 | 1 | -12.3
 | 5.9 | 0.236449 | 2 | -29.5 | 7.8 |
| AGC75 average | |

 | | -5.4 | | | |
 | 0.2 | | | | |
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 | | | | | |
| GC352 | 3442 | 1.141830

 | 4 | -7.9 | 3.1 | 0.510989 | 2
 | 1.1 | 0.348403 | 1 | 4.1 | 2.9 | 0.722696
 | 60 | 0.241581 | 1 | -6.9
 | 5.1 | 0.236449 | 2 | -33.0 | 7.0 |
| 6(777 | 2400 | 1 141940

 | 2 | 0.6 | 2.0 | 0 512296 | 2
 | 1.6 | 0 249402 | 1 | 2.0 | 2.0 | 0 722622
 | 97 | 0 241582 | 1 | -2.2
 | 5.2 | 0 226451 | 2 | -25.0 | 6.8 |
| 00222 | 3400 | 1.141040

 | 3 | 0.0 | 3.0 | 0.312350 | 2
 | 1.0 | 0.348403 | 1 | 3.5 | 2.5 | 0.723033
 | 67 | 0.241382 | 1 | -2.5
 | 3.5 | 0.230431 | 2 | -23.0 | 0.0 |
| GC368 | 3261 | 1.141835

 | 3 | -3.3 | 2.7 | 0.510369 | 2
 | -1.0 | 0.348403 | 1 | 3.8 | 2.8 | 0.723632
 | 15 | 0.241579 | 1 | -17.1
 | 4.7 | 0.236448 | 1 | -36.4 | 6.3 |
| 4GC445 | 3216 | 1.141833

 | 4 | -5.4 | 3.2 | 0.510727 | 2
 | -1.1 | 0.348405 | 1 | 7.6 | 3.1 | 0.722131
 | 93 | 0.241580 | 1 | -11.5
 | 5.3 | 0.236446 | 2 | -44.3 | 7.2 |
| HVO2 | | 1 141942

 | 6 | 2.4 | 2.0 | 0 512976 | 2
 | | 0.248404 | 1 | 65 | 2.0 | 0 721600
 | 59 | 0 241582 | , | -2.0
 | 6.6 | 0 226446 | , | -42.4 | 8.6 |
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 | 5 | 2.4 | 3.5 | 0.512570 |
 | | 0.540404 | | 0.5 | 5.5 | 0.721000
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 | 2 | 0.2 | 2.8 | 0.510981 | 1
 | | 0.248400 | 1 | 26 | 2.8 | 0 721711
 | 66 | 0 241577 | 1 | -2.2
 | 4.5 | 0 226448 | 1 | -9.7 | 6.2 |
| GC 150b #R2 | 3661 | 1.141825

 | 4 | -1.8 | 3.1 | 0.510981 | 2
 | | 0.348400 | 1 | 3.0 | 2.8 | 0.723316
 | 24 | 0.241578 | 1 | 4.2
 | 5.0 | 0.236452 | 2 | 5.6 | 6.9 |
| GC 150b average | |

 | | -0.8 | | | |
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| S-BA189 | 3553 | 1.141827

 | 6 | 0.4 | 5.0 | 0.511444 | 3
 | 1.1 | 0.348401 | 2 | 5.4 | 5.0 | 0.721973
 | 47 | 0.241577 | 2 | 0.4
 | 8.7 | 0.236451 | 3 | 1.7 | 11.1 |
| 00.320 | 3553 | 1 141932

 | | 4.2 | 2.0 | 0 510120 |
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 | * | -4.2 | 3.8 | 0.510128 | 2
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 | 34 | 0.241577 | 1 | -U.D
 | 0.1 | 0.230448 | 2 | -11.4 | 8.5 |
| 4132 #R1 | 3509 | 1.141824

 | 4 | -2.6 | 3.3 | 0.510621 | 2
 | | 0.348400 | 1 | 3.3 | 2.9 | 0.720851
 | 52 | 0.241576 | 1 | -2.4
 | 5.0 | 0.236448 | 2 | -10.2 | 7.3 |
| 132 #R2
132 average | 3509 | 1.141823

 | 4 | -3.8 | 3.9 | 0.510621 | 2
 | | 0.348402 | 1 | 9.0 | 3.4 | 0.722296
 | 19 | 0.241576 | 1 | -4.5
 | 5.9 | 0.236447 | 2 | -15.7 | 8.3 |
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| A32a | 3480 | 1.141821

 | 4 | -5.4 | 3.7 | 0.512140 | 2
 | 0.3 | 0.348402 | 1 | 7.5 | 3.1 | 0.722807
 | 176 | 0.241577 | 1 | 1.2
 | 5.5 | 0.236446 | 2 | -17.4 | 7.7 |
| A128 | 3465 | 1.141827

 | 3 | 0.1 | 2.6 | 0.511125 | 1
 | 0.2 | 0.348400 | 1 | 2.2 | 2.9 | 0.723051
 | 33 | 0.241579 | 1 | 8.0
 | 4.1 | 0.236453 | 1 | 10.9 | 4.2 |
| GC350 #R1 | 3455 | 1 141825

 | 5 | -19 | 4.5 | 0.511909 | 2
 | | 0 348401 | 1 | 4.4 | 3.9 | 0 720526
 | 68 | 0 241578 | 2 | 2.5
 | 74 | 0 236450 | 2 | -3.2 | 10.2 |
| GC350 #R2 | 3455 | 1.141829

 | 5 | 2.1 | 4.6 | 0.511913 | 2
 | | 0.348400 | 1 | 1.2 | 3.4 | 0.722572
 | 32 | 0.241576 | 1 | -5.7
 | 5.9 | 0.236450 | 2 | -0.8 | 7.7 |
| GC350 #R3
GC350 average | 3455 | 1.141825

 | 5 | -2.0 | 4.0 | 0.511911 | 2
 | 0.5 | 0.348400 | 1 | 3.5 | 3.7 | 0.724003
 | 34 | 0.241578 | 2 | 4.0
 | 6.7 | 0.236450 | 2 | -2.0 | 9.2 |
| acaso average | |

 | | 0.0 | | | |
 | 0.5 | | | | |
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| GC50 #R1 | 3458 | 1.141821

 | 4 | -5.4 | 3.9 | 0.511791 | 2
 | | 0.348401 | 1 | 4.6 | 3.9 | 0.720716
 | 47 | 0.241577 | 2 | -0.6
 | 6.6 | 0.236447 | 2 | -13.2 | 8.8 |
| GC50 average | 3430 | 1.141015

 | 4 | -6.1 | 3.7 | 0.311789 | 2
 | | 0.348400 | 1 | 1.5 | 3.4 | 0.722750
 | 30 | 0.241370 | 1 | -2.4
 | 0.0 | 0.230443 | 2 | -24.0 | 7.4 |
| GC 45 | 2445 | 1 141920

 | 4 | .6.2 | 2.1 | 0 512141 | 2
 | 0.0 | 0 249200 | 1 | -0.1 | 27 | 0 720799
 | 80 | 0 241575 | 1 | -7.4
 | 4.9 | 0 226449 | 1 | -71 | 6.2 |
| GC 43 | 3443 | 1.141020

 | 4 | -0.2 | 3.1 | 0.512141 | 2
 | 0.0 | 0.348355 | 1 | -0.1 | 2.7 | 0.720788
 | 63 | 0.241373 | 1 | -7.4
 | 4.5 | 0.230445 | 1 | -7.1 | 0.5 |
| GC473 | 3241 | 1.141830

 | 3 | 3.0 | 3.0 | 0.510548 | 1
 | -1.0 | 0.348401 | 1 | 4.0 | 2.2 | 0.722943
 | 45 | 0.241577 | 1 | -2.1
 | 3.9 | 0.236449 | 1 | -6.3 | 5.5 |
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 | ±2s.e. on last
decimals place | ¹⁴⁸ Nd/ ¹⁴⁴ Nd | ±2s.e. on last decimals place | μ ¹⁴⁸ Nd (ppm) | ±25.e. (ppm)
 | ¹⁵⁰ Nd/ ¹⁴⁴ Nd | ±2s.e. on last
decimals place | µ ¹⁵⁰ Nd (ppm) |) ±2s.e. (p |
| ample
errestrial stds 1. ar | n 1, run 2
nalytical sessior | ¹⁴² Nd/ ¹⁶⁴ Nd

 | **Nd of published
±2s.e. on last
decimals place | isotope data. Fe
μ ¹⁴² Nd (ppm) | ±2s.e. (ppm) | ¹⁴³ Nd/ ¹⁴⁴ Nd | ±2s.e. on last
decimals place
| ε143Nd* | ¹⁴⁵ Nd/ ¹⁴⁴ Nd | r to Table S1 of th
±2s.e. on last
decimals place | μ ¹⁴⁵ Nd (ppm) | y material.
±2s.e. (ppm) | ¹⁴⁶ Nd/ ¹⁴⁴ Nd
 | ±2s.e. on last
decimals place | ¹⁴⁸ Nd/ ¹⁴⁴ Nd | ±2s.e. on last
decimals place | μ ¹⁴⁸ Nd (ppm) | ±2s.e. (ppm)
 | ²⁵⁰ Nd/ ³⁴⁴ Nd | ±2s.e. on last
decimals place | µ ¹⁵⁰ Nd (ppm) |) ±2s.e. (p |
| ample
errestrial stds 1. ar
Ndi-1
Ndi-1 | n 1, run 2
nalytical sessior | ¹⁴² Nd/ ¹⁴⁴ Nd
1.141840

 | **Nd of published
±2s.e. on last
decimals place
8
6 | µ ¹⁴² Nd (ppm) | 23.3 | ¹⁴³ Nd/ ¹⁴⁴ Nd
0.512103
0.512101 | ±2s.e. on last
decimals place
| ε143Nd* | 145 _{Nd/} 144 _{Nd}
0.348402 | r to Table S1 of th
±2s.e. on last
decimals place | e supplementar
μ ¹⁴⁵ Nd (ppm)
-0.5 | y material.
±2s.e. (ppm)
5.5
4.1 | ¹⁴⁶ Nd/ ¹⁴⁴ Nd
0.723837
0.722755
 | ±2s.e. on last
decimals place | ¹⁴⁸ Nd/ ¹⁴⁴ Nd
0.241582
0.241582 | ±2s.e. on last
decimals place | μ ¹⁴⁸ Nd (ppm)
-3.9 | 10.3
 | ¹⁵⁰ Nd/ ¹⁴⁴ Nd
0.236455
0.236457 | ±2s.e. on last
decimals place | μ ¹⁵⁰ Nd (ppm)
-4.5 |) ±2s.e. (p |
| ample
errestrial stds 1. ar
(di-1
(di-1
Idi-1 | n 1, run 2 | ¹⁴² Nd/ ¹⁴⁴ Nd
1.141840
1.141835
1.141836

 | **Nd of published
±2s.e. on last
decimals place
8
6
6 | μ ¹⁴² Nd (ppm)
1.1
-3.8
-2.5 | 3.3
2.7
2.8 | ¹⁴³ Nd/ ¹⁴⁴ Nd
0.512103
0.512101
0.512103 | initial ^{car} Nd/ ^{car} Nd
<u>t2s.e. on last</u>
<u>decimals place</u>
3
2
3 | ε143Nd*
 | ¹⁴⁵ Nd/ ¹⁴⁴ Nd
0.348402
0.348402
0.348402 | r to Table S1 of th
±2s.e. on last
decimals place | e supplementar
<u>µ¹⁴⁵Nd (ppm)</u>
-0.5
0.5
-0.9 | y material.
±2s.e. (ppm)
5.5
4.1
5.2 | ¹⁴⁶ Nd/ ¹⁶⁴ Nd
0.723837
0.722755
0.722290
 | ±2s.e. on last
decimals place | ¹⁴⁸ Nd/ ¹⁴⁴ Nd
0.241582
0.241583
0.241583 | 2
2
2 | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6 | 10.3
7.7
8.6
 | ¹⁵⁰ Nd/ ⁵⁴⁴ Nd
0.236455
0.236457
0.236459 | ±2s.e. on last
decimals place | μ ¹⁵⁰ Nd (ppm)
-4.5
4.3
10.6 |) ±2s.e. (p
14.2
10.3
11.7 |
| ample
errestrial stds 1. ar
Ndi-1
Ndi-1
Ndi-1
Ndi-1 | n 1, run 2
nalytical sessior | ¹⁴² Nd/ ¹⁴⁴ Nd
1.141840
1.141835
1.141836
1.141836

 | **Nd of published
±2s.e. on last
decimals place
8
6
6
7
2 | 1.1
-3.8
-2.5
-2.2 | 3.3
2.7
2.8
3.1 | ¹⁴³ Nd/ ¹⁴⁴ Nd
0.512103
0.512101
0.512103
0.512103
0.512103 | initial ^{ast} Nd/ ^{ast} Nd
<u>±2s.e. on last</u>
<u>decimals place</u>
3
2
3
3 |
ε143Nd* | 145 _{Nd} / ¹⁴⁴ Nd
0.348402
0.348402
0.348402
0.348402
0.348402 | r to Table S1 of th
±2s.e. on last
decimals place
2
1
2
2
2 | e supplementar
<u>µ¹⁴⁵Nd (ppm)</u>
-0.5
0.5
-0.9
1.4
2.0 | y material.
±2s.e. (ppm)
5.5
4.1
5.2
5.6
6.0 | ³⁴⁶ Nd/ ¹⁶⁴ Nd
0.723837
0.722755
0.72290
0.722718
 | 125.e. on last
decimals place | ¹⁴⁸ Nd/ ¹⁴⁴ Nd
0.241582
0.241583
0.241583
0.241583 | ±2s.e. on last
decimals place | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6
-0.5 | 10.3
7.7
8.6
9.6
 | 0.236455
0.236457
0.236459
0.236459 | ±2s.e. on last
decimals place | μ ¹⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3 |) ±2s.e. (p
14.2
10.3
11.7
14.0 |
| ample
errestrial stds 1. ar
Vdi-1
Vdi-1
Vdi-1
Vdi-1
Vdi-1 | n 1, run 2 | 142 _{Nd} / ¹⁴⁴ Nd
1.141840
1.141835
1.141836
1.141836
1.141843
1.141843

 | **Nd of published
±2s.e. on last
decimals place
8
6
6
7
8
8
8 | μ ¹⁴² Nd (ppm)
1.1
-3.8
-2.5
-2.2
3.6
0.5 | 3.3
2.7
2.8
3.1
3.7
3.6 | ¹⁴³ Nd/ ¹⁴⁴ Nd
0.512103
0.512101
0.512103
0.512103
0.512102
0.512102 | initial ^{car} Nd/ ^{car} Nd
±2s.e. on last
<u>decimals place</u>
3
2
3
3
4
3 | ε143Nd*
 | 145Nd/ ³⁴⁴ Nd
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348401 | r to Table S1 of th
±2s.e. on last
decimals place
2
1
2
2
2
2
2 | μ ³⁴⁵ Nd (ppm)
-0.5
-0.5
-0.9
1.4
0.8
-2.2 | y material.
<u>+2s.e. (ppm)</u>
5.5
4.1
5.2
5.6
6.0
5.7 | ³⁴⁶ Nd/ ³⁶⁴ Nd
0.723837
0.722755
0.722718
0.722718
0.722830
0.721677
 | 17
88
65
15
62
76 | ¹⁴⁸ Nd/ ¹⁴⁴ Nd
0.241582
0.241583
0.241583
0.241583
0.241583
0.241583 | ±2s.e. on last
decimals place | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6
-0.5
-1.0
-3.0 | 10.3
7.7
8.6
9.6
10.6
10.0
 | ¹⁵⁰ Nd/ ¹⁴⁴ Nd
0.236455
0.236457
0.236459
0.236456
0.236455
0.236455 | ±2s.e. on last
d decimals place | μ ¹⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9 |) <u>±2s.e. (p</u>
14.2
10.3
11.7
14.0
14.8
14.5 |
| ample
errestrial stds 1. ar
Vdi-1
Vdi-1
Vdi-1
Vdi-1
Vdi-1
Vdi-1 | n 1, run 2 | 142 _{Nd} / ¹⁴⁴ Nd
1.141840
1.141835
1.141836
1.141836
1.141833
1.141843
1.141843
1.141843

 | *2s.e. on last
decimals place
8
6
6
7
8
8
8
7 | μ ¹⁴² Nd (ppm)
1.1
-3.8
-2.5
-2.2
3.6
0.5
1.5 | 3.3
2.7
2.8
3.1
3.7
3.6
3.2 | ¹⁴³ Nd/ ¹⁴⁴ Nd
0.512103
0.512101
0.512103
0.512103
0.512102
0.512102
0.512101
0.512104 | initial ^{ex} Nd/ ^{ex} Nd
±2s.e. on last
decimals place
3
2
3
3
4
3
4
3
4 | ε143Nd*
 | ¹⁴⁵ Nd/ ¹⁴⁴ Nd
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402 | r to Table S1 of th
±2s.e. on last
decimals place
2
1
2
2
2
2
2
2
2
2 | μ ¹⁴⁵ Nd (ppm)
-0.5
-0.9
1.4
0.8
-2.2
0.6 | x material.
<u>+2s.e. (ppm)</u>
5.5
4.1
5.2
5.6
6.0
5.7
5.9 | ³⁴⁶ Nd/ ³⁴⁴ Nd
0.723837
0.722755
0.72290
0.722718
0.722830
0.721677
0.722316
 | 125.e. on last
decimals place
17
88
65
15
62
76
95 | ¹⁴⁸ Nd/ ¹⁴⁴ Nd
0.241582
0.241583
0.241583
0.241583
0.241583
0.241582
0.241582 | ±2s.e. on last
decimals place
2
2
2
2
3
2
2
2
2
2
2
2
2
2
2
2
2
2
2 | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6
-0.5
-1.0
-3.0
-5.2 | 10.3
7.7
8.6
9.6
10.6
10.0
10.0
 | ²⁵⁰ Nd/ ⁵⁴⁴ Nd
0.236455
0.236457
0.236456
0.236457
0.236455
0.236455
0.236455 | 12s.e. on last
decimals place | μ ¹⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9
-4.1 |) ±2s.e.(p
14.2
10.3
11.7
14.0
14.8
14.5
14.2 |
| ample
errestrial stds 1. ar
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1 | n 1, run 2 | ¹⁴² Nd/ ¹⁶⁴ Nd
1.141840
1.141835
1.141836
1.141836
1.141839
1.141839
1.141839
1.141839
1.141839
1.141837

 | *2s.e. on last
decimals place
8
6
6
7
8
8
8
7
7
7 | μ ¹⁴² Nd (ppm)
1.1
-3.8
-2.5
-2.2
3.6
0.5
1.5
-1.6
-4.4 | 3.3
2.7
2.8
3.1
3.7
3.6
3.2
7.2
2.2 | ¹⁴³ Nd/ ¹⁴⁴ Nd
0.512103
0.512101
0.512103
0.512103
0.512103
0.512101
0.512101
0.512101
0.512101 | initial ^{ex} Nd/ ^{res} Nd
12s.e. on last
1 decimals place
3
3
4
3
4
7
7 | ε143Nd*
 | 145
Nd/ ¹⁴⁴ Nd
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402 | r to Table S1 of th
±2s.e. on last
decimals place
2
1
2
2
2
2
2
2
2
2
2
2
2
2
2 | μ ¹⁴⁵ Nd (ppm)
-0.5
0.5
-0.9
1.4
0.8
-2.2
0.6
-4.5
2.2 | x material.
+2s.e. (ppm)
5.5
4.1
5.2
5.6
6.0
5.7
5.9
12.3
72 | ³⁴⁶ Nd/ ³⁴⁴ Nd
0.723837
0.722755
0.722290
0.722718
0.722830
0.721677
0.722316
0.721402
 | 12s.e. on last
decimals place | 148 Nd/ ¹⁴⁴ Nd
0.241582
0.241583
0.241583
0.241583
0.241583
0.241582
0.241582
0.241582 | ±2s.e. on last
decimals place | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6
-0.5
-1.0
-3.0
-5.2
9.7 | 10.3
7.7
8.6
9.6
10.6
10.0
10.0
10.0
24.6
 | ¹⁵⁰ Nd/ ⁵⁴⁴ Nd
0.236455
0.236457
0.236456
0.236457
0.236455
0.236455
0.236455
0.236455
0.236455 | ±2s.e. on last
decimals place | μ ¹⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9
-4.1
7.0 |) ±2s.e. (p
14.2
10.3
11.7
14.0
14.8
14.5
14.2
32.8 |
| ample
errestrial stds 1. ar
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1
Ndi-1 | n 1, run 2 | ¹⁴² Nd/ ¹⁶⁴ Nd
1.141840
1.141835
1.141836
1.141836
1.141839
1.141839
1.141837
1.141837
1.141837

 | *2s.e. on last
decimals place
8
6
6
7
8
8
8
7
17
7
7 | μ ³⁴² Nd (ppm)
1.1
-3.8
-2.5
-2.2
3.6
0.5
1.5
-1.6
-1.4
1.7 | 3.3
2.7
3.3
3.1
3.7
3.6
3.2
7.2
3.3
3.0 | ¹⁴³ Nd/ ¹⁴⁴ Nd
0.512103
0.512101
0.512103
0.512103
0.512103
0.512104
0.512104
0.512104
0.512104 | initial ⁴² Nd/ ⁷⁴ Nd
<u>±2s.e. on last</u>
<u>1 decimals place</u>
3
2
3
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
5
1
1
1
1
1
1
1
1
1
1
1
1
1 | ε143Nd* |
145 _{Nd/} ¹⁴⁴ Nd
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348401
0.348402
0.348400
0.348401 | r to Table S1 of th
±2s.e. on last
decimals place
2
1
2
2
2
2
2
4
2
2
4
2
2 | μ ²⁴⁵ Nd (ppm)
-0.5
0.5
-0.9
1.4
0.8
-2.2
0.6
-4.5
-2.2
1.4 | x material.
+25.e. (ppm)
5.5
4.1
5.6
6.0
5.7
5.9
12.3
7.2
5.6
5.9
12.3
7.2
5.6 | ³⁴⁶ Nd/ ³⁶⁴ Nd
0.723837
0.722755
0.722290
0.722718
0.722830
0.721677
0.722316
0.721402
0.722926
0.722926
0.722926
 | 12s.e. on last
decimals place
17
88
65
15
62
76
95
110
35
69 | 148 Nd/ ¹⁴⁴ Nd
0.241582
0.241583
0.241583
0.241583
0.241583
0.241582
0.241582
0.241582
0.241585
0.241585 | ±2s.e. on last
decimals place
2
2
2
2
2
2
2
2
2
2
3
2
2
6
3
2
2
2
6
3
2 | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6
-0.5
-1.0
-3.0
-5.2
9.7
-2.4
3.5 | 10.3
7.7
8.6
9.6
10.6
10.0
10.0
24.6
12.0
10.0
 | ¹⁵⁰ Nd/ ⁵⁴⁴ Nd
0.236455
0.236457
0.236459
0.236455
0.236455
0.236455
0.236455
0.236455
0.236456 | 12s.e. on last
decimals place | μ ³⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9
-4.1
7.0
-1.7
2.9 | 14.2
10.3
11.7
14.0
14.8
14.5
14.2
32.8
16.0
14.6 |
| ample
errestrial stds 1. ar
kdi-1
kdi-1
kdi-1
kdi-1
kdi-1
kdi-1
kdi-1
kdi-1
kdi-1
kdi-1 | n 1, run 2 | 142 _{Nd} / ¹⁴⁴ Nd
1.141835
1.141835
1.141836
1.141836
1.141836
1.141837
1.141837
1.141837
1.141837
1.141837
1.141837

 | ************************************** | μ ³⁴² Nd (ppm)
1.1
-3.8
-2.5
-2.2
3.6
0.5
-1.6
-1.4
1.7
0.3 | 3.3
2.7
2.8
3.1
3.7
3.6
3.2
7.2
3.3
3.0
3.1 | ¹⁴³ Nd/ ¹⁴⁴ Nd
0.512103
0.512103
0.512103
0.512103
0.512103
0.512102
0.512104
0.512104
0.512104
0.512104 | initial ⁴² Nd/ ⁷⁴ Nd
<u>±2s.e. on last</u>
<u>1 decimals place</u>
3
3
3
4
3
4
7
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
3
4
4
3
4
4
4
4
4
4
4
4
4
4
4
4
4 | ε143Nd*
 145 _{Nd/} ³⁴⁴ Nd
0.348402
0.348402
0.348402
0.348402
0.348402
0.348402
0.348401
0.348401
0.348401
0.348401
0.348401
0.348402
0.348402 | r to Table S1 of th
±2s.e. on last
decimals place
2
2
2
2
2
2
2
2
4
2
2
2
2
2
2
2
2
2
2
2
2
2 | + ³⁴⁵ Nd (ppm)
-0.5
0.5
-0.9
1.4
0.8
-2.2
0.6
-4.5
-2.2
1.4
0.6
-4.5
-2.2
1.4
0.1 | x material.
<u>+2s.e. (ppm)</u>
5.5
4.1
5.2
5.6
6.0
5.7
5.9
12.3
7.2
5.6
6.7 | ³⁴⁶ Nd/ ¹⁴⁴ Nd
0.723837
0.722755
0.722290
0.722718
0.722316
0.72216
0.722316
0.722316
0.722316
0.722402
0.722926
0.722075
 | #2s.e. on last
decimals place
17
88
65
15
62
76
95
110
35
69
21 | 145 Nd/ ²⁴⁴ Nd
0.241582
0.241583
0.241583
0.241583
0.241583
0.241582
0.241582
0.241582
0.241582
0.241582 | +2s.e. on last
decimals place
2
2
2
2
3
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2
6
3
2
3
2
3
3
2
3 | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6
-0.5
-1.0
-3.0
-5.2
9.7
-2.4
3.5
2.3 | 10.3
7.7
8.6
10.6
10.0
10.0
24.6
12.0
10.0
11.2
 | 150Nd/544Nd
0.236455
0.236457
0.236459
0.236459
0.236455
0.236455
0.236455
0.236455
0.236456
0.236455
0.236456 | 12s.e. on last
decimals place | μ ³⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9
-4.1
7.0
-1.7
2.9
4.6 | 14.2
10.3
11.7
14.0
14.8
14.5
14.2
32.8
16.0
14.6
15.3 |
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errestrial stds 1. ar
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1.141840
1.141835
1.141836
1.141836
1.141836
1.141833
1.141837
1.141837
1.141837
1.141841
1.141837
1.141841

 | ************************************** | μ ¹⁶² Nd (ppm)
1.1
-3.8
-2.5
-2.2
3.6
0.5
1.5
-1.6
-1.4
1.7
0.3
2.9 | 2.7
2.8
3.7
3.6
3.2
7.2
3.6
3.2
7.2
3.3
3.0
3.1
3.1 | 2 ⁴³ Nd/ ⁵⁴⁴ Nd
0.512103
0.512101
0.512103
0.512103
0.512103
0.512104
0.512104
0.512104
0.512104
0.512104
0.512104 | initial ^{ex} Nd/ ^{-ex} Nd
<u>±2s.e. on last</u>
<u>±2s.e. on last
<u>±2s.e. on last</u>
<u>±2s.e. on last
<u>±2s.e. on last
<u>±2s.e</u></u></u></u> | ε143Nd* | 145 Nd/ ³⁴⁴ Nd
0.348402
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0.348401
0.348400
0.348401
0.348400
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0.348402
 | r to Table S1 of th
±22.e. on last
decimals place
2
1
2
2
2
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2
2
2
2
2
2
2 | μ ³⁴⁵ Nd (ppm)
-0.5
0.5
-0.9
1.4
0.8
-2.2
0.6
-4.5
-2.2
1.4
0.1
1.8 | x material.
+23.e. (ppm)
5.5
4.1
5.2
5.6
6.0
5.7
5.9
12.3
7.2
5.6
6.7
5.5
6.7
5.5
6.7
5.5 | 346 _{Nd} / ³⁴⁴ Nd
0.723837
0.722755
0.722290
0.72280
0.72280
0.722830
0.722830
0.722830
0.722431
0.722431
0.722926
0.722925
0.722951
0.722389 | #2s.e. on last
decimals place
17
88
65
15
62
76
95
110
25
69
12
98
 | ¹⁴⁸ Nd/ ¹⁶⁴ Nd
0.241582
0.241583
0.241583
0.241583
0.241583
0.241582
0.241582
0.241582
0.241582
0.241582
0.241583
0.241583 | ±2s.e. on last
decimals place
2
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2
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2
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2
2
5
6
3
2
2
3
3
3 | μ ^{L68} Nd (ppm)
-3.9
1.4
1.6
-0.5
-1.0
-3.0
-5.2
9.7
-2.4
3.5
2.3
-0.4 | 10.3
7.7
8.6
9.6
10.6
10.0
10.0
24.6
12.0
10.0
11.2
10.6 | 120 _{Nd} / ²⁴⁴
Nc
0.236455
0.236459
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0.236454
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0.236455
0.236457 | 12s.e. on last
decimals place | μ ¹⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9
-4.1
7.0
-1.7
2.9
4.6
-6.4 | 14.2
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 | ************************************** | μ ⁴² Nd (ppm)
1.1
-3.8
-2.5
-2.2
3.6
0.5
1.5
-1.6
-1.4
1.7
0.3
2.9
0.0
0.0 | t23.e. (ppm)
3.3
2.7
2.8
3.7
3.6
3.2
7.2
3.3
3.0
3.1
3.1
3.1
3.8
4.4 (23.d.) | ³⁴³ Nd/ ³⁴⁴ Nd
0.512103
0.512103
0.512103
0.512103
0.512103
0.512104
0.512104
0.512104
0.512104
0.512104
0.512104
0.512104 | initial ^{ex} Nd/ ^{-ex} Nd
<u>±2s.e. on last</u>
<u>tec:nals place</u>
3
2
3
4
4
7
4
3
4
5
 | <u>£143Nd</u> * | 145 Ndy ¹⁴⁴ Nd
0.348402
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0.348400
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0.348403
0.348403
0.348403 | r to Table S1 of th
±23.e. on last
decimals place
2
1
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3 | μ ¹⁴⁵ Nd (ppm)
-0.5
-0.9
-0.9
-2.2
0.6
-2.2
0.6
-2.2
-4.5
-2.2
1.4
0.1
1.8
3.5 | y material.
<u>\$28.e. (ppm)</u>
5.5
4.1
5.2
5.6
6.0
5.7
5.9
12.3
7.2
5.6
8.3 | 346 _{Nd} / ³⁴⁴ Nd
0.723837
0.722755
0.722290
0.722316
0.7224316
0.7224316
0.7224316
0.722492
0.722926
0.722491
0.722491
0.722491
0.722491
 | #2s.e. on last
decimals place
17
88
65
15
62
76
62
75
10
35
69
12
98
61 | ¹⁴⁸ Nd/ ¹⁶⁴ Nd
0.241582
0.241583
0.241583
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0.241582
0.241582
0.241582
0.241583
0.241583
0.241583
0.241583 | ±2s.e. on last
decimals place
2
2
2
2
3
2
2
2
3
2
2
3
3
2
3
3
3
3 | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6
-0.5
-1.0
-3.0
-5.2
9.7
-2.4
3.5
-0.4
3.5 |
10.3
7.7
8.6
9.6
10.0
10.0
10.0
14.6
12.0
10.0
11.2
10.6
13.5 | 120 _{Nd} / ²⁴⁴ Nc
0.236455
0.236459
0.236459
0.236455
0.236455
0.236455
0.236455
0.236455
0.236458
0.236459
0.236459 | 12s.e. on last
decimals place
3
3
3
3
3
3
3
4
3
5 | μ ¹⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9
-4.1
7.0
-1.7
2.9
4.6
-6.4
12.5 | 14.2
10.3
11.7
14.0
14.8
14.5
14.2
32.8
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14.6
15.3
13.9
19.8 |
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 | *** Nd of published
************************************ | isotope data. Fr
¹⁴⁰ Nd (ppm)
1.1
-3.8
-2.5
-2.2
3.6
0.5
1.5
-1.6
-1.4
1.7
0.3
2.9
0.0
0.0 | 125.e. (ppm)
3.3
2.7
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4.4 (2s.d.) | ³⁴³ Nd/ ³⁴⁴ Nd
0.512103
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<u>t2s.e.</u> on last
<u>decimals place</u>
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 | ε143Nd* | 145 Ndy ¹⁴⁴ Nd
0.348402
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0.348403 | r to Table S1 of th
±2s.e. on last
decimals place
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3 | μ ¹⁶⁵ Nd (ppm)
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3.5 | y material.
<u>\$25.e. (ppm)</u>
5.5
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8.3 | ²⁴⁶ Nd/ ³⁴⁸ Nd
0.72280
0.72275
0.722718
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 | 12s.e. on last
decimals place
17
88
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61 | ¹⁴⁸ Nd/ ¹⁴⁴ Nd
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3 | <u>µ¹⁴⁸Nd (ppm)</u>
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-1.6
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-7.2 |
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7.7
8.6
9.6
10.0
10.0
10.0
24.6
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11.2
10.6
13.5 | 1 ⁵⁰ Nd/ ³⁴⁴ Nd
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1 decimals place
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4
3
4
3
5 | μ ¹⁵⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9
-4.1
7.0
-1.7
2.9
4.6
-6.4
12.5 |) ±25.e. (p
14.2
10.3
11.7
14.0
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32.8
16.0
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 | "Nd of published
\$25.e. on last
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6 | isotope data. Fr
<u>µ¹⁶²Nd (ppm)</u>
1.1
-3.8
-2.5
-2.2
3.6
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1.5
-1.6
-1.4
1.7
0.3
2.9
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0 | 1 12s.e. (ppm)
3.3
2.7
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3.6
3.2
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5.0 | Sm/ Nd and
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0.512104 | initial **Nd/~*No
12s.e. on last
decimals place
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 | ε143Nd* | 145 please refe
145 Nd/ ¹⁴⁶ Nd
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decimals place
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2 | uplementar
u ¹⁴⁰ Nd (ppm)
-0.5
0.5
-0.9
1.4
0.8
-2.2
0.6
-4.5
-2.2
1.4
0.1
1.8
3.5
-0.7 | y material.
<u>125.e. (ppm)</u>
5.5
5.6
6.0
5.7
5.6
6.0
5.9
12.3
7.2
5.6
6.7
5.6
6.7
5.8
8.3
4.4
4.4
4.1
5.9
4.1
5.9
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6.0
5.9
4.2
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6.0 | 245 Nd/ ³⁴⁵ Nd
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0.722755
0.722270
0.722218
0.722830
0.722316
0.721677
0.722316
0.722316
0.722920
0.722929
0.722929
0.722929
0.72295
0.72295
0.722572
 | +2s.e. on last
decimals place
17
18
88
65
15
62
76
95
110
35
69
95
12
98
61 | 146 Nd/144 Nd
0.241582
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0.241584 | 225.e. on last
decimals place
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3
3
3
3 | μ ¹⁴⁵ Nd (ppm)
-3.9
-1.4
-1.6
-0.5
-1.0
-3.0
-5.2
9.7
-2.4
3.5
2.3
-0.4
3.5 |
10.3
77
8.6
9.6
10.6
10.0
10.0
10.0
24.6
12.0
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13.5 | 150 _{Nd} / ³⁴⁴ Nd
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5 | μ ¹⁵¹⁰ Nd (ppm)
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-7.9
-4.1
7.0
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2.9
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12.5 |) ±25.e. (r
14.2
10.3
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3 | isotope data. Fr
µ ¹⁴² Nd (ppm)
1.1
-3.8
-2.5
-2.5
-5.5
-5.5
-1.6
-1.4
1.7
0.0
0.0
0.0
-3.4
-3.5 | 1 42s.e. (ppm)
3.3
2.7
2.8
3.1
3.7
3.6
3.2
7.2
3.3
3.6
3.2
7.2
3.3
3.0
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225.e. on last
1 decimals place
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5 | <u>e143Nd</u> * | 145 please refe
145 NdJ ¹⁴⁶
Nd
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0.348399 | to Table S1 of th
±25.e. on last
decimals place
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<u>µ¹⁶⁰Nd (ppm)</u> -0.5 0.5 -0.9 1.4 0.8 -2.2 0.6 -2.2 1.4 0.1 1.8 3.5 -0.7 -4.8 -0.7 -4.8 -0.7 -4.8 -0.7 -4.8 -0.7 -4.8 -0.7 -4.8 -0.7 -4.8 -0.7 -4.8 -0.7 -4.8 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.7 -0.4 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 -0.1 | v material.
<u>*25.e. (ppm)</u>
5.5
4.1
5.2
5.6
6.0
5.7
5.9
12.3
7.2
5.6
6.7
5.6
6.7
5.6
8.3
4.4
2.6 | 115 Nd/154 Nd
0.7223837
0.722755
0.722755
0.722718
0.7221677
0.722316
0.7221402
0.722349
0.722349
0.722339
0.722572
0.722677
0.722672
 | 12s.e. on last
decimals place
17
88
65
15
62
76
95
110
35
69
12
98
61 | 148 Nd) ¹⁴⁴ Nd
0.241582
0.241583
0.241583
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0.241582
0.241584
0.241584
0.241584
0.241584
0.241575
0.241575 | 225.e. on last
decimals place
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3
3
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2
1 | μ ¹⁴⁸ Nd (ppm)
-3.9
1.4
1.6
-0.5
-1.0
-3.0
-5.2
9.7
-2.4
3.5
-2.4
3.5
-0.4
3.5
-9.3
-1.12 | 10.3
7.7
8.6
9.6
10.0
10.0
10.0
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10.0
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10
 | 110 Nd/ ³⁴⁴ Nd
0.236455
0.236457
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0.236446 | 122.e. on last
1 decimals place
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5 | -4.5
4.3
10.6
-3.3
18
-7.9
-4.1
7.0
-1.7
2.9
4.6
-6.4
4.6
-6.4
12.5
-19.7
-24.2 | 14.2
14.2
10.3
11.7
14.0
14.8
14.5
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32.8
16.0
14.6
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13.9
19.8
10.8
6.8 |
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kdr 1
kd | 1, run 2
nalytical session
ession
nalytical session | 1.141840
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1.141839
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1.141823
1.141823

 | Nd of published
125.e. on last
decimals place
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4 | isotope data. Fr
<u>µ⁴⁴²Nd
(ppm)</u>
1.1
-3.8
-2.5
-2.2
3.6
0.5
-1.6
-1.4
1.7
0.3
0.0
0.0
-3.4
-3.5
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3.8
4.4 (2s.d.)
5.0
3.0
3.1 | Sm/ Nd and
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0.512107 | initia "Nd/" Nc
s25.e. on last
decimals place
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5 | E143Nd* | 145 NdJ ***Nd 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348402 0.348403 0.348403 0.348403 0.348403 0.348403 0.348403 0.348403 0.348403 0.348403 0.348403 0.348403 0.348403 0.348403 0.348404 0.348403 0.348403 0.348403 0.348403 0.348403
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+25.e. on last
decimals place
2
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2 | e supplementar
<u>µ¹⁴⁵Nd (ppm)</u>
-0.5
0.5
-0.9
1.4
0.8
-2.2
0.6
-4.5
-2.2
1.4
0.1
1.8
3.5
-0.7
-4.8
8.8 | v material.
225.e. (ppm)
5.5
4.1
5.2
5.6
6.0
5.7
5.9
12.3
7.2
5.6
6.7
5.5
4.3
4.4
4.4
2.6
2.9
4.4
4.4
4.4
4.4
4.4
4.4
4.4
4 | 346 _{Nd/} ²⁴⁴ Nd
0.722837
0.722755
0.722290
0.722380
0.722316
0.722167
0.72216
0.72216
0.72240
0.722316
0.72290
0.722075
0.722075
0.722389
0.722572
0.722617
0.720617
0.720615
0.720515
 | #25.e. on last
decimais place
17
18
88
65
15
62
15
62
15
62
19
95
10
35
69
10
35
69
61
61
61
61
22 | 148 NdJ ¹⁴⁴ Nd
0.241582
0.241583
0.241583
0.241583
0.241583
0.241582
0.241582
0.241582
0.241584
0.241584
0.241584
0.241575
0.241574
0.241578 | 22se.on last
decimals place
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2
2 | <u>µ¹⁴⁸Nd (ppm)</u>
-3.9
-1.4
-0.5
-1.0
-0.5
-1.0
-0.5
-2.4
-2.4
-2.4
-2.3
-0.4
-3.5
-9.3
-11.2
5.9
-11.2
5.9 | 10.3
7.7
8.6
9.6
10.0
10.0
10.0
10.0
10.0
11.2
10.6
13.5
7.7
4.9
5.0
 | 120 Nd/244 No
0.236455
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0.236446
0.236445
0.236445
0.236445
0.236445 | 225.e. on last
decimals place
3
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3
3
3
3
3
3
3
3
3
3 | μ ¹⁵⁰ Nd (ppm)
-4.5
4.3
10.6
-3.3
1.8
-7.9
-4.1
7.0
-4.1
7.0
-4.1
2.9
4.6
-6.4
12.5
-19.7
-24.2
15.3 | 14.2
14.2
10.3
11.7
14.0
14.8
14.5
14.2
32.8
16.0
14.6
15.3
13.9
19.8
10.8
6.8
6.6
6.6 |
| ample
errestrial stds 1. ar
Vdri-1
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5 | 145 Ntd/144 Ntd
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0.72299
0.722975
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0.72205
0.722572
0.722659
0.722572
 | 225.e. on last
decimals place
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84 | 144 NdJ ¹⁴⁴ Nd
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-3.9
1.4
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3 | <u>µ¹⁵⁰Nd (ppm)</u>
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-3.3
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-1.7
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16.1 | 14.2
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125.e. on last
decimals place
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±2s.e. on last
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2 | upplementar u¹⁴⁵Nd (ppm) -0.5 -0.5 -0.6 -4.5 -0.6 -4.5 -0.1 1.8 -0.7 -4.8 8.8 9.2 -0.1 -2.2 | y material.
<u>123.e. (ppm)</u>
5.5
4.1
5.2
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8.3
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2.4 | *** ₅ Nd/*** _{Nd}
0.722837
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0.722659
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0.720515
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 | \$25.e. on last
decimals place
decimals place
65
62
76
69
95
110
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12
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24
48
67 | 148 NdJ ¹⁴⁴ Nd
0.241582
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decimals place
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1 | ¹/₂ ¹⁴⁸Nd (ppm) -3.9 1.4 -0.5 -1.0 -3.0 -7.0 -2.4 3.5 -9.3 -1.12 5.9 7.7 2.4 | 10.3
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 | 153 _{Nd/} 541 _{Nd}
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decimals place
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5 | μ ³⁵⁰ Nd (ppm)
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4.3
10.6
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1.8
-7.9
-4.1
7.0
-1.7
2.9
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12.5
-19.7
-24.2
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16.1
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14.2
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| ample
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3 | isotope data. Fr
¹¹⁰ Nd (ppm)
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Table S1: Summary of major and trace element as	well as ¹⁴⁷ Sm- ¹⁴³ Nd and ¹⁷⁶ Lu- ¹⁷⁶ Hf isotope data
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	Ancient Gneis	ent Gneiss Complex							Barberton Gre	enstone Be	lt							
Sample	AGC 150b [*]	AGC 370 ^a	AGC 75 ^b	AGC 50 ^c	AGC 350"	AGC 45 ^c	AGC 352 ^b	AGC 222 ^b	AGC 368	AGC 473	AGC 445"	KS-BA 189"	error (%)	AGC 372 ^d	BA 156	BA 132 [#]	ZA-32a"	BA 128°
						amph									amph			
			tonalitic	meta-	foliated	komatiitic				throndhiemitic		tholeiitic		felsic volcanic	tholeiitic			tonalitic
Lithology	grey gneiss	tonalite	gneiss	komatiite	metagabbro	halsalt	grey gneiss	amphiholite	granodiorite	gneiss	grey gneiss	hasalt		rock	nillow basalt	throndhiemite	tholeiite	gneiss
Age (Ma)	3661	3552	3478	3458	3455	3445	3442	>3400	3261	3241	3216	3553		3552	3530	3509	3480	3465
	Gooirs (Diggs		Trawola				Nawano									Staunrdorn		Theorpruit
F	Grielss (Piggs	Diana Daala	Casies	Duvelile	Addisona Divers	Duvelile	Ngwarie	Kulauta	Haute Cuite	Duvalila	Diago Dagle	Condensuit Fra		The second sit for	Theorem it for	Steynsuorp	Kamati Fas	Distan
Formation	PedK)	PIggs Peak	Glieiss	Dwallie	withinane kiver	Dwalle	Glieiss	KUDULA	Usulu suile	Dwallie	PIggs Peak	Sanuspruit Fill		meespruit Fm.	meespruit Fm.	Pluton	KOMALI FIII.	Pluton
	6.0																	
iviajor element	S (%)			10.0														
SIDZ	69.7	78.1	63.5	49.6	55.4	49.1	70.1	46.8	64.9	68.7	58.0	52.1		62.80	53.7	71.9	53.2	69.1
TIO2	0.390	0.160	0.577	0.463	1.08	0.775	0.493	1.66	0.790	0.487	1.15	0.500		0.80	0.964	0.295	0.771	0.27
AI203	12.6	12.4	15.9	4.56	15.0	9.76	14.7	14.6	16.7	16.4	18.4	13.8		17.04	13.9	15.3	12.1	15.0
Fe2O3	5.69	1.47	5.71	6.14	9.89	3.18	4.19	15.4	5.45	3.18	7.46	10.6		5.76	11.8	2.59	11.6	2.95
FeO				7.04		9.98												
MnO	0.0700	0.0400	0.0911	0.252	0.131	0.245	0.0604	0.201	0.0559	0.0405	0.0813	0.163		0.08	0.175	0.0509	0.193	0.0297
MgO	2.43	0.450	3.07	23.3	6.38	15.3	1.48	7.16	1.59	0.862	1.93	10.01		2.05	6.20	0.570	8.94	1.35
CaO	1.41	1.22	5.35	8.40	7.00	9.80	2.49	10.9	4.25	2.96	5.76	10.35		4.91	10.8	2.24	9.65	2.79
K2O	2.54	1.64	1.50	0.0315	1.46	0.0917	1.44	2.11	1.19	1.76	1.59	0.537		3.17	0.0366	2.10	0.165	1.47
Na2O	1.71	4.78	4.14	0.126	3.49	1.35	4.92	0.803	4.83	5.50	5.31	1.81		3.16	2.39	4.94	3.27	5.35
P2O5	0.0900	0.0400	0.121	0.0526	0.158	0.122	0.131	0.301	0.259	0.152	0.345	0.0799		0.24	0.0870	0.0611	0.0906	0.0892
Trace elements	s (ppm)			*														
Li	241		45.1		17.2		14.0	12.2		63.4	178				7.55	111	5.76	41.0
Sc	4.82	1.72	12.2	16.6	25.2	25.5	5.91	41.0		2.10	3.27	30.3	6		35.9	1.86	27.1	3.47
v	21.6		96.3	116	152	225	54.8	404		27.2	104	165	4		326	14.9	218	62.5
Cr	17.5	6.70	73.4	1891	205	1765	28.8	127		7.97	4.10	1			147	5.16	691	438
Co	11.1	4.32	21.0		41.6	90.0	10.6	62.1		5.23	15.7	58.6	3		46.1	3.00	52.1	7.76
Ni	12.2	18.3	60.4	1231	139	403	17.9	127		3.80	5.23				101	4.09	173	39.8
Cu	109	-	37.9	54.8	25.3	51.0	3.09	100		10.5	37.9	67.4	7		155	8.16	123	4.86
Zn	164		65.9	86.0	125	121	77.7	121		68.4	128	74.5	19		83.5	48.5	74.4	50.0
Ga	23.5		18.6		22.8		20.7	18.8		21.0	22.9	12.7	4		15.2	20.2	11.4	18.2
Rb	229	61.5	76.9	4.98	56.3	10.0	38.5	69.4		28.8	50.6		-		0.416	33.0	2 71	53.1
5r	121	215	202	9.50	419	22.0	58.5	142		26.0	400	102	6		116	212	109	574
51 V	50 /	45	15 5	24.0	410 20 E	22.0	16.2	27.4		11.2	435	16.7	0		22.2	12.4	195	5.93
7-	33.4	124	147	40.4	130	22.0	170	27.4		192	210	10.7	7		23.2	13.4	10.5	121
21	340	134	147	40.4	133	5.00	170	2.00		0.00	210	3.10	14		2.5	0.20	3.00	4.69
140	55.0	0.37	1.10	2.02	0.170	5.00	0.354	0.304		0.242	9.25	0.510	14 C		2.03	0.117	0.000	4.00
CT			0.124		0.170		0.133	0.504		0.245	0.305	0.015	17		0.272	0.117	0.550	
Ca			0.124		0.200		0.152	0.187		1.77	0.525	0.0949	1/		0.164	0.155	0.111	
50			0.0012		1.09		1.55	0.570		1.//	3.52	0.508	0		0.104	0.164	0.023	
50			0.0812	2.46	0.0400		0.0669	0.0691		0.0567	0.0442				0.220	0.295	0.0651	2.59
CS D	21.2	699	1.19	2.16	0.850	3.91	0.760	2.67		2.46	13.8				0.116	6.38	0.272	2.56
ва	537	633	296	6.79	234	1.00	376	45.0		384	446	89.1	5		24.3	4/9	53.9	322
La	51.2	20.8	28.2	3.84	12.2	4.06	20.1	5.30		28.8	37.3	8.71	4		3.28	19.6	4.40	9.02
Ce	93.8	40.8	56.9	9.05	32.7	10.8	36.5	13.8		37.8	47.6	18.0	4		8.87	25.4	11.34	16.2
Pr	11.2	3.49	6.45	1.24	4.97	1.72	4.65	2.06		6.20	9.21	2.22	4		1.38	4.11	1.66	2.00
Nd	41.8	12.2	24.0	5.56	24.1	8.19	18.1	10.2		23.2	37.5	9.08	3		7.21	15.2	7.94	8.20
Sm	8.88	1.55	4.16	1.50	6.54	2.36	3.73	3.06		4.02	6.80	2.18	7		2.38	2.91	2.29	1.82
Eu	1.37	0.760	1.14	0.404	1.66	0.700	1.04	1.25		1.07	1.90	0.600	7		0.887	0.735	0.756	0.64
Gd	9.15	1.22	3.77	1.70	7.02	2.82	3.37	4.01		3.14	5.26	2.52	6		3.17	2.58	2.84	1.59
Tb	1.55	0.150	0.492	0.269	1.15	0.490	0.510	0.690		0.391	0.626	0.405	7		0.570	0.390	0.496	0.21
Dy	9.88	0.880	2.70	1.60	7.10	3.42	2.96	4.58		1.92	2.70	2.71	16		3.90	2.29	3.28	1.15
Но	2.04	0.160	0.525	0.321	1.41	0.760	0.580	0.970		0.337	0.390	0.586	7		0.836	0.454	0.688	0.21
Er	5.76	0.440	1.45	0.916	3.81	2.3	1.60	2.72		0.865	0.857	1.69	6		2.38	1.29	1.94	0.57
Tm	0.83	0.070	0.221	0.130	0.54	0.311	0.229	0.406		0.119	0.103	0.255	7		0.364	0.193	0.290	0.0810
Yb	5.24	0.460	1.45	0.826	3.39	1.87	1.49	2.68		0.725	0.611	1.68	7		2.43	1.30	1.92	0.51
Lu	0.760	0.080	0.227	0.117	0.488	0.360	0.222	0.418		0.101	0.0844	0.251	9		0.356	0.221	0.298	0.0720
Hf	9.65	3.39	3.64	0.975	3.15	1.91	4.47	2.02		4.48	5.23	1.78	4		1.61	4.34	1.63	3.23
Та	2.54	0.420	0.459	0.138	0.483	0.263	0.544	0.230		0.786	0.486	0.202	11		0.165	0.921	0.216	0.400
w			0.142		0.250		0.144	2.306		0.120	0.293	0.294	10		0.127	0.392	0.105	
т	1		0.39		0.280		0.285	0.331		0.402	0.631	1			0.0361	0.336	0.0280	
Pb	9.60	10.6	6.03	0.551	3.94	0.379	4.78	5.17		9.87	9.69	2.43	7		0.552	6.795	0.707	7.33
Th	14.5	3.00	4.01	0.520	0.680	0.476	3.86	0.440		4.71	4.75	1.43	7		0.252	3.73	0.403	1.88
U	3.73	0.980	0.743	0.135	0.260	0.125	0.625	0.153		0.838	2.55	0.203	7		0.0868	0.705	0.101	
Isotopic compo	sition			•								1						
Sm (ppm)	9.01	1.97	3.80	1.36	6.09	2.21	3.71	2.85	4.90	4.93	6.80	1.99		6.16	2.14	3.44	2.10	1.85
Nd (ppm)	42.5	13.7	21.8	5.16	22.4	7.68	18.4	9.41	30.2	30.5	37.5	8.42		32.8	6.54	18.9	7.31	8.67
147Sm/144Nd	0.1280	0.0868	0.1050	0.1592	0.1642	0.1743	0.1220	0.1830	0.0979	0.0978	0.1095	0.1426		0.1135	0.1983	0.1097	0.1738	0.1290
143Nd/144Nd	0.511019	0.510137	0.510548	0 511775	0 51 1922	0 512138	0.511004	0.512410	0 510422	0.510545	0.510736	0.511431		0.510660	0.512728	0.510609	0 512134	0.511105
+	14	13	11	9	10	9	16	8	8	6	7	7		9	7	13	8	20
	0.72	1.44	0.22	0.20	10	0.05	1.15	1.62	1.05	1.00	, 10	1 12		0.62	, , , , , , , , , , , , , , , , , , , ,		0.20	
2 NO(t)	0.72	1.44	0.22	-0.30	0.50	U.U5	1.15	1.62	-1.85	-1.00	-1.10	1.13		-0.62	u.87	-0.40	0.29	0.20
	0.770		0.046			0.000			0.453	0.111		0.057		0.000	0.000		0.005	0.0766
Lu (ppm)	0.778	0.0988	0.216	0.120	0.488	0.289	0.222	0.414	U.157	0.111	0.0840	0.257		0.393	0.368	0.221	0.295	0.0766
HT (ppm)	8.39	4.47	3.64	0.952	3.12	1.74	4.47	2.22	7.18	4.02	5.23	1.77		5.55	1.69	4.27	1.70	3.68
-^~Lu/'''Hf _o	0.0132	0.00314	0.00843	0.0179	0.0222	0.0236	0.00705	0.0265	0.0031	0.00343	0.00229	0.0206		0.0100	0.0310	0.00735	0.0246	0.00296
¹⁷⁶ Hf/ ¹⁷⁷ Hf ₀	0.281410	0.280755	0.281164	0.281786	0.282105	0.282186	0.281174	0.282472	0.280896	0.280894	0.280854	0.281991		0.281139	0.282689	0.281014	0.282255	0.280738
± .	7	7	5	22	5	10	6	7	7	7	11	11		6	6	5	5	7
εHf(t)	2.53	2.09	2.41	1.70	2.80	2.33	5.39	6.00	0.92	-0.30	0.23	3.50		-1.07	2.98	-4.30	2.60	0.10
				-					-		-	1		-	-		-	-
Sm/Nd	0.212	0.143	0.174	0.264	0.272	0.288	0.202	0.302	0.162	0.162	0.181	0.236		0.188	0.328	0.182	0.288	0.213
		-		-			-		-	-	-				-	-		-
*Krönor et al. 3	014																	

*Kröner et al. 2014 *Hoffmann et al. 2016 *Kröner & Tegtmeyer 1994 *Kröner et al. 2013 *Sample BA 115 from Kröner et al. 2016 *AGC 50: TE and Isotopes by Hoffmann et al in prep. *this study, ages: pers. comm. A. Kröner 2016

Supplementary information S2: Sample digestion and chemical separation for ¹⁴²Nd/¹⁴⁴Nd analyses

Sample powders were digested in a mixture of concentrated HF-HNO₃ in Parr® pressure vessels for 48 hours and dried down with one additional milliliter of $HClO_4$. Subsequently, 5 ml conc. HNO_3 was added to the samples and dried down immediately. After evaporation, the samples were dissolved in 6 ml 6 N HCl overnight. After full equilibration was reached, the samples were evaporated to dryness.

For purifying Nd from the whole rock sample solutions, four chemical separations were implemented. The first separation was performed on ca. 20 cm long and 6 mm wide Teflon columns filled with AG-50W-x8 200-400 µm mesh resin. Samples were loaded in 2.5 N HCl. Major elements were eluted with 44 ml of 2.5 N HCl and heavy REE were eluted in 10 ml 4 N HCl. The remaining REE fraction was collected in 29 ml of 6 N HCl and subsequently dried down. In a second stage, the REE fraction was diluted in 0.2 ml of a mixture of 10 N HNO₃ and 20 mM NaBrO₃ and loaded on 12 mm long and 7 mm wide PET columns filled with 1 ml of Eichrom Ln-Spec 50-100 µm resin to remove Ce from the REE fraction. Details are given in Tazoe et al. (2007). After elution of the REE fraction, a mixture of 6 N HCl and H₂O₂ was added to the columns to reduce Ce and ensure that no Ce⁴⁺ is present. This chemical separation was done twice to reduce the Ce content to negligible levels. In a third step 6 cm long and 4 mm wide quartz columns filled with 300 mg of Eichrom Ln-Spec 25-50 µm resin were used to purify the Nd from all other REE. In order to do that, the samples were loaded in 0.2 ml of 0.2 N HCl. The light REE were eluted with 10.5 ml of 0.2 N HCl. Subsequently, the Nd fraction was collected in 3 ml of 0.25 N HCl. However, after checking the elemental content in the samples at the ICP-MS, some samples still showed comparatively high Ba concentrations. Consequently, a fourth separation was applied to remove Ba from the samples. For this separation, columns filled with 1 ml of AGW50-X8 200-400 µm mesh resin were used. The samples were loaded in 2.5 N HCl. The Ba was eluted with 2 N HNO₃ and the pure Nd fraction was subsequently collected in 6 N HCl. The total procedural blank determined by ICP-MS for Nd is 300 pg, The blank contribution was negligible in comparison to the Nd fractions for analyzed samples (> 500 ng).

Tazoe H., Obata H. and Gamo T. (2007) Determination of cerium isotope ratios in geochemical samples using oxidative extraction technique with chelating resin. J. Anal. At. Spectrom. 22, 616-622. Supplement S3: Analytical methods BA 132, BA 156, ZA-32a, KS-BA 189, AGC 222, AGC 350, AGC 445, AGC 473

Samples BA 132, BA 156, KS-BA 189, ZA-32a, AGC 350, AGC 368, AGC 445, and AGC 473 were analyzed for their whole rock major element compositions by X-ray fluorescence spectrometry (XRF) on $Li_2B_4O_7$ -flux fusion discs using a PANalytical Axios X-ray spectrometer at the University of Cologne, Germany (Table S1). The loss on ignition (LOI) for each sample was determined by baking 1 g of rock powder in a muffle type furnace at 1000°C for 24 hours.

Samples BA 132, BA 156, KS-BA 189, ZA-32a, AGC 350, AGC 445, and AGC 473 were also analyzed for their trace element compositions. Sample powders were digested in Parr® pressure vessels in concentrated HF-HNO₃ for 72 hours and dried down with adding one milliliter of HClO₄. Subsequently 2 ml concentrated HNO₃ was added to the samples and dried down immediately. After evaporation to dryness, the samples were diluted in 3 % HNO₃ for trace element analysis. Samples BA 132, BA 156, and ZA-32a were analyzed at the University of Kiel, Germany, using an AGLIENT 7500cs quadrupole inductively coupled plasma mass spectrometer (ICP-MS). The analytical procedures followed Garbe-Schönberg (1993). Sample KS-BA 189 was analyzed at the Freie Universität Berlin using a Thermo Finnigan Element XR ICP-MS. Samples were diluted by dilution factors of 14000 to 64000 depending on the trace element concentrations of the samples. In order to calibrate the measured intensities of the low, middle and high masses, an internal standard solution of 1 ppb Ge-In-Re was added to the end dilution. The end dilutions were measured against a calibration curve of several dilutions of BHVO-2 ranging from 11.000- to 600.000-fold dilutions that were also doped with a 1 ppb Ge-In-Re solution. Furthermore, two REE solutions containing 1 ppb and 0.4 ppb Ba, La, Ce, Pr, Nd, and Sm were measured along with the samples in order to determine the oxide ratio that was produced within the plasma during measurements. Following this procedure, relative errors for the REEs were usually around 5 % and range from 4 to 19 % for the HFSE, LILE, and Sc, V, Cr, Co, Ni, Cu, Zn (Table S1).

Samples BA 132, BA 156, KS-BA 189, ZA-32a, AGC 222, AGC 350, AGC 368, AGC 445, and AGC 473 were analyzed for their Hf and Nd isotopic compositions and Lu, Hf, Sm, Nd concentrations (Table S1). The analyses were obtained by isotope dilution using mixed ¹⁷⁶Lu-¹⁸⁰Hf and ¹⁴⁹Sm-¹⁵⁰Nd tracers following the protocols of Münker et al. (2001) and Weyer et al. (2002). Measurements were carried out using a Thermo Scientific Neptune multi-collector ICP-MS at the joint facility of the Cologne and Bonn universities (Germany), operated in static mode. Chemical separation of Hf and Nd followed the procedures outlined in Pin & Zalduegui (1997) and Münker et al. (2001). Reference materials AGV-2 and BHVO-2 were measured along with the samples to determine the accuracy of the results.

Measured values of ¹⁷⁶Hf/¹⁷⁷Hf and ¹⁴³Nd/¹⁴⁴Nd were corrected for mass fractionation using the exponential law and ¹⁷⁹Hf/¹⁷⁷Hf = 0.7325 and ¹⁴⁶Nd/¹⁴⁴Nd = 0.7219, respectively. All values are given relative to a ¹⁷⁶Hf/¹⁷⁷Hf of 0.282160 for the AMES solution that is isotopically indistinguishable

from JMC-475, and relative to a ¹⁴³Nd/¹⁴⁴Nd of 0.511859 for the La Jolla Nd standard. Samples were analyzed at the same concentrations as the standards, i.e. 24 ppb for AMES and 20 ppb for La Jolla. Typical external reproducibilities for Nd and Hf isotope measurements were $\pm 0.3 \epsilon$ -units. CHUR parameters used to calculate epsilon values are from Bouvier et al. (2008).

Figure S4: Evaluation of metamorphic disturbance. A) μ^{142} Nd anomalies vs. (La/Yb)_{PMN}. B) μ^{142} Nd anomalies vs. Pb content. No correlation can be observed between the μ^{142} Nd anomalies and elevated LREE or LILE. Consequently, we assume that metamorphic effects did not disturb the μ^{142} Nd anomalies of our AGC and BGB samples.

