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Mesoarchean synchronous emplacement of TTG gneisses and potassic granitoids in the Nyabessane granite-greenstone terranes, NW Congo Craton (southern Cameroon): Zircon U Pb geochronology, petrogenesis and tectonic implications

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1 **Mesoarchean synchronous emplacement of TTG gneisses and potassic**
2 **granitoids in the Nyabessane granite-greenstone terranes, NW Congo Craton**
3 **(southern Cameroon): Zircon U-Pb geochronology, petrogenesis and tectonic**
4 **implications**

5
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18

19 **Abstract**

20 Archean granitoids played key roles in the generation and differentiation of the Archean
21 continental crust and provide clues to understand crustal processes in the early Earth. Abundant
22 Mesoarchean granitoids were emplaced in the Nyabessane granite-greenstone terrane (NGB),
23 part of the Ntem Complex of the Northwest Congo Craton. They include charnockites, tonalite-
24 trondhjemite-granodiorite (TTG), granitic and monzogranitic gneisses. Here, we present a
25 geochemical and geochronological (zircon LA-ICP-SF-MS U-Pb) study of these granitoids to
26 determine their petrogenesis and to better constrain the crustal evolution of the Ntem Complex.
27 Field and petrographic observations indicate that most of these granitoids underwent extensive
28 metamorphism and deformations, associated with anatexis. Zircon U-Pb dating results suggest
29 that the charnockite, TTGs and granitic gneisses, and monzogranites have emplacement ages
30 of 2910 ± 11 Ma, 2870–2865 Ma and 2852 ± 31 Ma, respectively. The charnockites have low
31 SiO₂ (55–58 wt.%) and high Al₂O₃ (16–18 wt.%), CaO (7–8 wt%) and MgO (~ 4.5 wt%)

32 content with Mg# ~ 54, and exhibit magnesian, metaluminous characteristics of the Cordilleran
33 granitoid-type formed in magmatic arc. The 2.87–2.86 Ga TTG gneisses are silica-rich (55–58
34 wt.% SiO₂), sodic (3–5 wt.% Na₂O, Na₂O/K₂O = 1–3), with HREE-depleted, and display the
35 typical Archean medium- to low pressure TTG geochemical features groups. Their chemical
36 compositions are characteristics of TTG-like melts derived from the partial melting of hydrated
37 low- to high-K metabasic/thickened lower crust at various depths followed by magmatic
38 differentiation during ascent. When compared to the TTG gneisses in the NGB, the ~2.87 Ga
39 granitic gneisses are K-rich, and high Gd/Yb, Th/Yb, Th/Nb, Sr/Y and La/Yb ratios but lower
40 MgO, Yb, V, Y, Cr, Ni and Sr contents, matching typical Archean hybrid and potassic granitic
41 rocks. We propose that the granitic gneisses were derived from the intra-crustal melting of a
42 pre-existing felsic crust. The granitic and the TTG gneisses were generated contemporaneously
43 through the same magmatic event at ~ 2.87–2.86 Ga. The ~ 2852 Ma monzogranitic gneisses
44 are ferroan and metaluminous rocks, and show LREE enrichment with strongly fractionated
45 REE patterns and positive Eu anomalies. Geochemical features, together with the presence of
46 ~ 2.9 Ga-old inherited zircon grains are consistent with the remelting of Mesoarchean
47 granitoids. Considering the petrogenetic, regional geological and geochronological data, the
48 Mesoarchean granitoid magmatism of the Ntem Complex was likely generated via complex
49 transitional geodynamic regimes involving subduction and accretion processes.

50 **Keywords:** Na- and K-rich granitoids, Mesoarchean, subduction-accretion, Continental crust
51 evolution, Congo Craton, Cameroon

52

53

54 **1. Introduction**

55 The generation and differentiation of the early continental lithosphere represent two of the
56 most important and challenging questions for the understanding of the early evolution of Earth's
57 tectonics and how the crust was produced and recycled. Archean cratons (4.0–2.5 Ga) are
58 predominantly composed of granitoid rocks of the sodic tonalite-trondhjemite-granodiorite

59 (TTG) suite and high-K calc-alkaline granitoids, which hence played a critical role during the
60 assembly of early Earth continental crust (Condie, 2005; Martin et al., 2005; Moyen, 2011;
61 Laurent et al., 2011; Halla et al., 2017). Thus, their geochronological, petrological and
62 geochemical signatures provide the most direct information on how the early continental crust
63 was generated and evolved (Moyen, 2011; Moyen and Laurent, 2018; Windley et al., 2021;
64 Sotiriou et al., 2023; Hastie et al., 2023).

65 Though, there is today a consensus that TTG magmas are sourced from the partial melting
66 and/or crystallization of hydrated basaltic-melts with residual amphibole and garnet (Martin et
67 al., 2005), the tectonic setting related to their formation remains, controversial. Proposed
68 geodynamic models include partial melting of over-thickened mafic arc crust (Hastie et al.,
69 2016; Nagel et al., 2012), subducted oceanic crust (Martin et al., 2014), subducted oceanic
70 plateau (Martin et al., 2005), fractional crystallization of hydrous arc basalts (Kleinhanns et al.,
71 2003; Jagoutz et al., 2013) and/or prolonged differentiation of thickened basaltic plateaus,
72 triggered by underplating of long-lasting mantle upwellings (Johnson et al., 2017; Bédard,
73 2018). This controversy is linked to the large geochemical diversity of TTGs, suggesting that
74 the melting of mafic rocks occurred at different depths, either at “low pressure”(LP-) TTG (<0.6
75 Gpa), “medium pressure”(MP-) TTG (1–1.5 GPa), or “high pressure” (HP-) TTG (≥ 1.5 GPa)
76 regimes (Moyen, 2011). Recent work has proposed that HP-TTGs would in fact be the product
77 of mass fractionation of melt generated from the metasomatically enriched lithospheric mantle,
78 rather than generated via the melting a mafic crust at convergent plate margins (Smithies et al.,
79 2019). Also, although the TTG suit could be formed by the differentiation and evolution of a
80 parental tonalitic melt in the upper crust (Kendrick and Yakymchuk, 2020; Laurent et al., 2020),
81 most TTG plutons were emplaced within the middle crust (e.g. Martin, 1994). During the late
82 Archean (3.2–2.5 Ga), the progressive appearance of voluminous diverse K-rich granitoids in
83 nearly all ancient cratons has been interpreted as the record of a significant geodynamic change

84 on the Earth (Laurent et al., 2014; Halla et al., 2017). These high-K granitoids were either
85 formed by the partial melting of pre-existing crust (e.g. Sylvester, 1994) and/or by the melting
86 of mixed mantle and crustal sources (Zhu et al., 2009; Halla et al., 2017; Moyen et al., 2017;
87 Joshi et al., 2017).

88 There has been widespread TTG and high-K granitic magmatism in the northern-western
89 Congo Craton (NWCC), as seen in the Ntem Complex during the late Archean (3.0–2.5 Ga)
90 (Fig.1b; Toteu et al., 1994; Tchameni et al., 2000; Shang et al., 2004a; Pouclet et al., 2007;
91 Shang et al., 2010; Takam et al., 2009; Li et al., 2016; Thiéblemont et al., 2018; Akame et al.,
92 2020a). In the Ntem Complex (southern Cameroon), the charnockites, TTG suites, and high-K
93 granitoids are spatially associated throughout the craton. This abundant Meso-to Neoproterozoic
94 various granitoids in the Ntem Complex could reflect significant coeval change in geodynamic.
95 This contribution presents a new field, petrographic, whole-rock geochemical, and zircon LA-
96 -ICP-SF-MS U-Pb study for the Mesoarchean TTG gneisses and high-K granitoids of the
97 Nyabessane area. The results have implications on their petrogenesis, and formation and
98 evolution of continental crust of the NWCC during the Mesoarchean time.

99 **Fig. 1**

100 **2. Geological setting**

101 The Congo Craton is one of the oldest terranes (*ca.* 3.4–1.8 Ga) of central Africa, bordered
102 by Pan-African Neoproterozoic mobile belts and covered by Paleoproterozoic to Phanerozoic
103 supracrustal formations (e.g. Thiéblemont et al., 2018). The geology of the Congo Craton is
104 characterized by the presence of large Archean and Paleoproterozoic shields, which have been
105 poorly investigated compared to the Neoproterozoic mobile belts.

106 The Ntem Complex (Fig. 1b) is bordered towards the northwest by the Paleoproterozoic
107 Nyong Complex and to the north by the Yaoundé Group of the Pan-African Orogenic Belt of
108 Central Africa (e.g. Nzenti et al., 1988; Owona et al., 2011, 2021; Toteu et al., 2022). These
109 three entities are delimited by two major thrust faults (Maurizot et al., 1986). The Ntem

110 Complex mainly consists of Mesoarchean charnockites, TTG gneisses, metamorphosed
111 supracrustal formations of the so-called banded iron formation (BIF) – paragneiss – amphibolite
112 – pyroxenite - norite sequences, together with minor Neoproterozoic mafic, syenitic and granitic
113 plutons or dykes (e.g. Maurizot et al., 1986; Toteu et al., 1994; Tchameni et al., 2000; Shang et
114 al., 2004a, 2004b; Takam et al., 2009; Li et al., 2016; Akame et al., 2020a). Mesoarchean
115 charnockite and TTG suites cover about 80% of the complex and were emplaced at ca. 3.2–
116 2.85 Ga (Takam et al., 2009; Tchameni et al., 2010; Li et al., 2016; Toteu et al., 2022; Akame
117 et al., 2020a, 2023). The narrow and elongated greenstone belts are variably folded together
118 with the granite-gneissic basement and were deposited ~3.05–2.87 Ga ago (Tchameni et al.,
119 2004; Chombong and Suh, 2013). The Ntem Complex experienced high-grade metamorphism
120 associated with migmatization and polyphase deformation from ~2.84 to 2.74 Ga (Tchameni
121 et al., 2010; Akame et al., 2020a, 2021), and late-stage granite plutons and dolerite dykes were
122 emplaced between 2.75 and 2.65 Ga (Tchameni et al., 2000, 2010; Shang et al., 2010; Akame
123 et al., 2020a, 2021). Based on differences in the lithological association, bulk-rock geochemical
124 composition, emplacement ages as well as structural style, Akame et al. (2020a, 2023)
125 suggested that the Ntem Complex resulted from a protracted Archean (3.20 Ga and 2.85 Ga)
126 subduction-accretion process that included the reworking of a minor Paleo-Archean
127 component.

128 Three deformation events have been recognized in the Ntem Complex (Ntomba et al.,
129 2020; Akame et al., 2020b, 2021). The first deformation event D1 is characterized by a regional
130 steeply dipping foliation (S_1) associated with stretching lineation (L_1), and small-scale isoclinal
131 folds (F_1). This regional strain phase was coeval with the Mesoarchean high-temperature
132 metamorphism and the migmatization of TTGs as well as with the emplacement of the
133 charnockitic suites. The pressure-temperature (P-T) condition of metamorphism is not well
134 established. Available metamorphic data range between granulite and amphibolite facies

135 metamorphism (Maurizot et al., 1986; Tchameni et al., 2010; Ntomba et al., 2016, 2020; Akame
136 et al., 2020b). The second regional deformation event (D_2) was responsible for the folding of
137 the S_1 foliation by F_2 folds and the formation of sinistral/dextral C_2 shear zones (Akame et al.,
138 2020b; Ntomba et al., 2020). This D_2 episode was coeval with the intrusion of high-K granite
139 at ca 2.75 Ga (Akame et al., 2020b, 2021). The last episode (D_3) was mainly brittle, forming
140 dominantly NE to N-trending faults, which were probably reactivated during the
141 Paleoproterozoic orogeny event in the NW Congo Craton (Owona et al., 2011; Akame et al.,
142 2020b).

143 **Fig. 2**

144 **3. Field relationship and petrography**

145 *3.1. Field observations*

146 The Nyabessane granite-greenstone terrane consists mainly of charnockites, TTG and
147 granitic gneisses (Fig. 2), with minor felsic (monzogranites) and mafic dykes, as well as banded
148 iron formations (Fig. 1b). The charnockites, TTG and granitic gneisses are highly deformed and
149 cross-cut by numerous leucogranitic and doleritic dikes (Supplementary Fig. S1a, b, c).
150 Occasionally, charnockites contain enclaves of norites and amphibolite, and therefore post-date
151 the earliest mafic crust in the region. In the site of the Menve'ele hydroelectric power dam (Fig.
152 1b), the TTG and granitic gneisses are strongly sheared and foliated and steeply dip toward NW
153 to NNW (Fig. 2b). The contacts between TTG and granitic gneisses are frequently obscured by
154 intensive migmatization and ductile deformation, and the assemblage constitutes a strongly
155 banded lithology (Fig. 2b, c). Locally, this lithology also includes norite and/or amphibolite
156 layers as well as granitic leucosomes (Fig. 2c-e). Both the TTG and granitic gneisses are also
157 cross-cut by some epidosite veins, indicating late hydrothermal activity (Supplementary Fig.
158 S1d). The monzogranites show ductile deformation and gneissic fabric paralleling the foliation
159 of the TTG gneisses (Fig. 2h). Moreover, TTG and granitic gneisses are widely cut by
160 leucogranitic veins that are either folded or sheared and appear to be of local anatectic origin.

161 3.2. Petrography

162 The charnockites are medium-grained with a granoblastic texture and have a typical mineral
163 assemblage of plagioclase-hypersthene-quartz-clinopyroxene-biotite and hornblende, and
164 minor K-feldspar. Magnetite, zircon, ilmenite, and apatite are the accessory phases (Fig. 3a, b).
165 Biotite and clinopyroxene invariably shows retrogression to chlorite \pm epidote \pm sericite (Fig.
166 3b, c). However, hypersthene and hornblende are locally well-preserved (Fig. 3a, b), indicating
167 granulite-facies peak metamorphism. The TTG gneisses are commonly medium-grained and
168 granoblastic; they are composed dominantly of plagioclase, quartz, hornblende, biotite and
169 minor K-feldspar \pm clinopyroxene, with accessory zircon, apatite, ilmenite and magnetite (Fig.
170 3c, d). Quartz in these gneissic rock form ribbons with undulate extinction and feldspar are
171 elongated parallel to the foliation (Fig. 3c). Leucosome in TTG gneisses shows myrmekite in
172 perthitic and micro-perthitic K-feldspar near contact with plagioclase (Fig. 3d). Replacement
173 of biotite by chlorite as well as sericitization of plagioclase are common in the rest of the
174 samples. Compared to charnockites, orthopyroxene is scarce in TTG gneisses, and their mineral
175 assemblage with biotite, hornblende, plagioclase, and K-feldspar suggests granulite-facies
176 metamorphism. The granitic gneisses are light to pinkish grey, medium-grained and show
177 mineral assemblages of quartz, K-feldspar, and plagioclase with minor biotite (Fig. 3e-f).
178 Zircon, ilmenite, and apatite are accessory phases. The foliation plane is defined by elongated
179 feldspar or quartz, as well as biotite flakes. Plagioclase crystals are moderately altered to
180 clinozoisite, epidote, and sericite (Fig. 3e), and biotite is partially chloritized. Quartz grains are
181 stretched, folded, and extensively recrystallized, routinely displaying undulose extinction
182 suggesting subgrain rotation recrystallization (Fig. 3e, f). Finally, the monzogranitic gneisses
183 are pink (Fig. 2h), foliated to slightly mylonitic, and porphyritic with quartz and perthitic K-
184 feldspar phenocrysts oriented within a fine-grained feldspar-quartz-biotite-amphibole matrix
185 (Fig. 3g-h). Myrmekite is common along minor-scale shear zones. Likewise, those in granitic

186 gneisses, quartz phenocrysts show intense dynamic recrystallization, with a strong grain size
187 comminution. Minor biotite, hornblende, and Fe-Ti oxide occur in the groundmass together
188 with accessory apatite, zircon, ilmenite, and magnetite (Fig. 3g-h).

189

190 **Fig. 3**

191 **4. Analytical methods**

192 *4.1. Whole-rock geochemistry*

193 Eighteen fresh granitoid samples devoid of secondary alteration were crushed and
194 pulverized using an agate mill at the G-Time Laboratory at the Université libre de Bruxelles
195 (ULB), Belgium. Major-element compositions were determined on powder aliquots after
196 alkaline fusion. About 50 mg of sample were mixed with a stream of high-purity lithium
197 metaborate and tetraborate in a graphite crucible and heated for 10 minutes at 1000 °C. The
198 bead, after cooling, was dissolved for several hours with a stirring magnet in 5% HNO₃. For
199 major element compositions, the diluted samples were then measured with the USGS BHVO-
200 2 and RGM2 standards to evaluate the accuracy, which is better than 2% (2RSD) for each
201 element, using a synthetic calibration curve and Y as internal standard. Loss on ignition (LOI)
202 was determined after 1 h at 1000 °C. Trace elements were measured on the Agilent 7700 ICP-
203 MS at ULB, using the USGS BHVO-2 and RGM2 standards, using a synthetic calibration curve
204 and In as internal standard. The total reproducibility estimated using multiple USGS rock
205 standards is better than 10%.

206 *4.2. LA-ICP-SF-MS Zircon U-Pb dating*

207 Four samples of the best-preserved felsic gneisses (charnockite, TTG, granitic gneiss, and
208 monzogranite) of the Nyabessane granite-greenstone belt were selected for zircon U-Pb laser
209 ablation inductively coupled plasma sector field mass spectrometry (LA-ICP-SF-MS) age
210 dating. Zircon separation procedures were carried out at Laboratoire G-Time at Université libre
211 de Bruxelles. Selected samples have been gently crushed and sieved, and the heavy minerals

212 were recovered using heavy liquid (methylene iodide) and a Frantz magnetic separator, and
213 finally handpicked under a stereo microscope. At the Institute of Geosciences of the University
214 of Campinas (IG-UNICAMP), zircon grains were mounted in epoxy resin and polished with
215 diamond paste to show their internal structures. The crystals were imaged by BSE (back-
216 scattered electron) and CL (cathodoluminescence) imaging at the Isotope Geology Laboratory
217 of the Institute of Geosciences of the University of Campinas. The laser equipment consists of
218 a Photon Machines Excite 193-nm system equipped with a HelEx 2 ablation cell coupled to an
219 ICP-MS Thermo Scientific Element XR. The reference material zircon 91500 (1065.4 ± 0.3
220 Ma, Wiedenbeck et al., 1995) was used for correction of element fractionation as well as
221 instrumental drift. The Peixe reference zircon (564 ± 4 Ma, Dickinson and Gehrels, 2003) was
222 used to monitor the quality of the reduction procedures. During the analytical session, 14
223 analyses of Peixe zircon yielded 560.5 ± 3.4 Ma. Concordia and weighted average diagrams
224 were obtained with the software IsoplotR (Vermeesch, 2018).

225 **Table 1.**

226 **5. Results**

227 **5.1. Whole-rock major and trace element compositions**

228 The bulk-rock major and trace element data are listed in Table 1 and presented in Fig.
229 4. All samples are calc-alkaline rocks with SiO_2 contents varying between 55.9 and 77.5 wt.%.
230 The TTG gneisses scattered within the diorite, tonalite to granodiorite fields, whereas both the
231 granitic gneisses and monzogranite cluster in the monzogranite and granite fields (Fig. 4a). The
232 charnockites show mainly tonalitic composition, whereas the TTG gneisses encompass the
233 tonalite, granodiorite, trondhjemite and granite fields (Fig. 4b). The granitic gneisses and
234 monzogranite samples plot also in the field of granitic rocks (Fig. 4b).

235 **Fig. 4**

236 The charnockites have high Al_2O_3 , Fe_2O_3 , MgO, CaO, with Mg# (molar $[\text{MgO}/(\text{MgO} +$
237 $\text{FeO}^*)] = 53\text{--}55$), and low SiO_2 (56–58 wt%) relative to most TTG gneisses, though there is

238 some overlap between the t quartz-richest diorite and the tonalite. Except the sample JA22, both
239 charnockites and TTG gneisses are calcic to calc-alkalic and magnesian rocks (Fig. 4d-e). In
240 terms of the Aluminium Saturation Index (ASI), the charnockites are metaluminous (molar
241 $A/CNK = 0.75-0.77$), whereas the TTG gneisses are metaluminous to weakly peraluminous
242 (molar $A/CNK = 0.74-1.03$) (Table 1; Fig. 4f). Despite the variation in Na_2O , most charnockites
243 and TTG gneisses are sodic ($K_2O/Na_2O = 0.29 - 0.80$), except for sample MNN1 with high K_2O
244 ($K_2O/Na_2O = 1.03$) that plots in the granite field (Fig. 4b). In a K_2O vs. SiO_2 diagram (Fig.5f),
245 the TTG gneisses plot in the medium-to-high-K calc-alkaline series fields, whereas the
246 charnockites fall in the calc-alkaline series fields. Al_2O_3 , Fe_2O_3t , MgO , CaO , Cr , Ni , V , Co and
247 $Mg\#$ are all negatively correlated with SiO_2 (Fig. 5, S1), generally forming broad continuous
248 trends between charnockites and TTG gneisses, with the charnockites having more mafic
249 compositions ($TiO_2 + MnO + Fe_2O_3t + MgO > 11$ wt%) and higher Ni (> 34 ppm) and Cr (> 75
250 ppm). In addition, the majority of TTG gneisses are characterized by typically high Ba , Sr , Rb ,
251 Zr , Hf , and light rare earth elements (LREEs), but low, Ni (average ~ 17 ppm), Cr (average \sim
252 29 ppm), Co (average ~ 12 ppm), Y (< 34 ppm) and Sr/Y ratio ($12.7-113.1$), similar to other
253 Archean TTGs (e.g. Martin et al., 2005; Moyen, 2011).

254 Compared to the TTG gneisses, the granitic gneisses and monzogranites have an expanded
255 SiO_2 ($73-77$ wt.%) as they include much more silica-rich members than the TTG gneisses
256 (Table 1, Fig. 4). They are K_2O -rich (with $4.14-6.04$ wt% K_2O) and exhibit pronounced K-
257 enrichment with high K_2O/Na_2O ($1.01-2.41$) ratio, and all granitic gneiss and monzogranite
258 samples fall on the field occupied by Archean hybrid and potassic granitic rocks (Fig.4c). Like
259 the NGB TTG gneisses, the granitic gneisses are magnesian ($FeOt/(FeOt+MgO) = 0.67-0.75$),
260 but alkali-calcic and weakly peraluminous (molar $A/CNK = 1.08-1.10$ at > 73 wt.% SiO_2) (Fig.
261 4d-e-f). In comparison, the monzogranites belong to the calcic to alkali-calcic series, most of
262 them are ferroan and metaluminous granitoids (Fig.4e-f). Sample U.2.1 with high $Mg\#$ (> 40),

263 magnesian ($\text{FeOt}/(\text{FeOt} + \text{MgO}) = 0.72$), and weakly peraluminous ($A/\text{CNK} = 1.05$) character
264 at 73 wt.% SiO_2 , is similar to the host gneisses. Although most NGB granitoids show typical
265 features of I-type granitoids (Fig. 4f), the granitic gneisses and monzogranites are characterized
266 by lower TiO_2 , Al_2O_3 , MgO , Fe_2O_3 , CaO , P_2O_5 , Sr, Y, V, Ni, Nb, heavy rare earth elements
267 (HREEs) and $\text{Na}_2\text{O}/\text{K}_2\text{O}$, and higher K_2O , Sr/Y, Th/Yb, Th/Nb, La/Yb, Gd/Yb and Th/Ce than
268 the TTG gneisses (Figs. 5, and Table 1 and Fig. S2). The Ce/Th (~1.5-1.9) is relatively constant
269 in high-K granitoids. Except sample U2.1, all monzogranite samples display low Mg# (< 40)
270 relatively to other granitoids of the Nyabessane area.

271 **Fig. 5.**

272 On the Chondrite-normalized rare earth element diagrams (Fig. 6a-c), the charnockites
273 and TTG gneisses show moderately to strongly fractionated REE, expressed as high $(\text{La}/\text{Yb})_N$
274 = 9.31–17.47 and $(\text{La}/\text{Yb})_N = 19.0$ –89.3 (where $_N$ indicates normalization to chondrite),
275 respectively. TTG gneisses have negative to slightly positive europium anomalies ($\text{Eu}/\text{Eu}^* =$
276 0.3–1.4). LREE/HREE (~ 13.9–71.3) and $(\text{Gd}/\text{Yb})_N$ (~1.9–5.1) ratios are variable but generally
277 greater for the TTG gneisses. The granitic gneisses and monzogranite are also enriched in
278 LREEs with $(\text{La}/\text{Yb})_N = 59.3$ –131.3 and $(\text{La}/\text{Yb})_N = 128.4$ –175.9, respectively (Fig. 6e-g),
279 similar to the TTG gneisses, but they have lower total REE concentrations (Table 1). Positive
280 Eu anomalies ($\text{Eu}/\text{Eu}^* = 1.12$ –1.76) characterize the monzogranites, while the granitic gneisses
281 exhibit small negative to positive Eu anomalies ($\text{Eu}/\text{Eu}^* = 0.82$ –0.95, and $\text{Eu}/\text{Eu}^* = 1.9$ for
282 sample JA1).

283 A common feature of all analyzed granitoid rocks of Nyabessane area is the presence of
284 prominent negative Nb-P-Ti and positive K, Pb, Zr-Hf anomalies on the multiple trace element
285 diagram normalized to the primitive mantle (Fig. 6b-d, f-h). The granitic gneisses and
286 monzogranites have higher Zr_N/Nb_N (4.8–18.4 and 12.5–164.1), Th_N/Nb_N (26–438 and ≥ 150)
287 and La_N/Nb_N (7.2–73.8 and ≥ 47) ratio than most of the charnockite and TTG gneiss samples

288 ($Zr_N/Nb_N < 8$, $Th_N/Nb_N \leq 82$ and $La_N/Nb_N \leq 30$). Charnockitic sample JA8 has pronounced Pb-
289 undepleted and U-depleted ($U < 0.01$ ppm) values with relative lower Zr_N/Nb_N (0.73) and
290 U_N/Nb_N (0.02) ratio, (Fig. 6b).

291 **Fig.6.**

292

293 **5.2. Zircon U-Pb dating**

294 Zircon grains from four representative samples, including one charnockite (JA12), one
295 gneissic TTG (JA11), one granitic gneiss (JA1), and one monzogranite (U2) were dated by the
296 laser ablation sector field inductively coupled plasma mass spectrometry (LA-ICP-SF-MS) U-
297 Pb geochronological method. The GPS coordinates and analytical results of the zircon-bearing
298 samples are listed in supplementary Table 1. The representative cathodoluminescence images
299 of the zircon grains and Wetherill concordia diagrams are shown in Fig.7.

300 **5.3.1 Charnockite (sample JA12: N02°14'28.1"/E010°13'26.5")**

301 Zircon grains of sample JA12 show mostly elongated, irregular or prismatic shapes and
302 display oscillatory zonings on the cathodoluminescence (CL) images (Fig. 7a), indicating their
303 igneous origins (Corfu, 2003). Some zircon crystals exhibit complex dark structureless cores or
304 recrystallization/re-equilibration and alteration microtextures (Fig.7a). Xenocrystic core, as
305 well as a very thin rim, are also observed (Fig. 7a). Thirty-six core-rim U-Pb analyses were
306 conducted on thirty-one zircon grains, with variable concentration of U (47–998 ppm) and Th
307 (12–544 ppm) and moderate Th/U ratio of 0.13–1.06. In detail, most of spot analyses of the
308 rims are concordant compared to the cores even though they have similar Th/U ratio (Table
309 S1). Xenocrystic zircons have low Th/U (~ 0.25–0.28) ratio and yield older $^{207}Pb/^{206}Pb$ apparent
310 ages of 3024 ± 32 Ma (spot Zr43c) and 3121 ± 27 Ma (spot Zr32c) relative to other magmatic
311 core zircons. (Fig. 7e). Nineteen analyses of the cores (with >65% of concordance) yield an
312 upper intercept age of 2908 ± 14 Ma (MSWD = 2.8), which is consistent with the upper intercept
313 age of 2912 ± 20 Ma (MSWD = 0.72) yielded by twelve rim analyses (Supplementary Data,

314 Fig. S3a-b). Taking together, both core and rim analyses of concordant to discordant grains
315 yield an upper intercept date of 2910 ± 11 Ma and a lower intercept date of 682 ± 97 Ma (2σ ; n
316 $= 30$; $MSWD = 1.5$; Fig. 7e). Zircon grain Zr6 shows partially preserved oscillatory zoning
317 with convoluted and thickened bands (Fig. 7a). Rim spot Zr6r of this grain is more discordant
318 than the core with a $^{207}\text{Pb}/^{206}\text{Pb}$ date of 2839 ± 24 Ma (103% concordance, spot Zr6c, Table S1
319 and Fig. 7e). The zircon grain Zr38 exhibit a weakly zoned core surrounded by two outer
320 overgrowths, and the dark outer yielded a younger $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2733 ± 29 Ma (100% of
321 concordance spot Zr38c2; Fig. 7e).

322 **Fig. 7**

323 5.2.2. TTG gneiss (sample JA11: $N02^{\circ}22'14.4''/E010^{\circ}20'49.5''$)

324 Zircon grains from the TTG gneiss sample JA11 are euhedral to subhedral and show good
325 oscillatory zoning and core-rim structure in the CL images (Fig. 7b). Forty spots from 29 zircon
326 grains were analyzed both in the cores and in the rims. All analyses have moderate to high U
327 (84–834 ppm) and Th (73–1222 ppm) contents with high Th/U ratio of 0.20–1.62, and without
328 any evident difference between the cores and the rims. The igneous growth or sector zoning and
329 high Th/U ratio are characteristics of magmatic zircons (Hoskin and Schaltegger, 2003). In
330 addition, like the charnockite, there is no chemical difference between the cores and rims within
331 these zircons (Table S1). The majority of analyses from the core domains yielded an upper
332 intercept age of 2870 ± 9 Ma ($n = 30$, $MSWD = 2.9$) with the weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ date
333 of 2863 ± 6 Ma ($n = 18$, $MSWD = 0.52$), which is similar to a concordia age of 2864 ± 8 Ma (n
334 $= 9$, $MSWD = 0.65$) for the rims (Supplementary Data, Fig. S3c, d). Thirty-nine analyses,
335 acquired both within core and rim domains define a discordia line with an upper intercept date
336 of 2870 ± 8 Ma (2σ ; $n = 39$, $MSWD = 2.3$), which is similar within error with the weighted
337 mean $^{207}\text{Pb}/^{206}\text{Pb}$ date of 2865 ± 5 Ma ($MSWD = 0.36$) calculated using 21 near-concordant to
338 concordant analyses (Fig. 7f). One spot analysis (Zr3c) of the dark core of zircon Zr3 without

339 rim zoning (Fig. 7b), yields a young apparent $^{207}\text{Pb}/^{206}\text{Pb}$ date of 2760 ± 24 Ma (100% of
340 concordance; Fig. 7f).

341 5.2.3. Granitic gneiss (sample JA1: $N02^{\circ}14'28.1''/E010^{\circ}13'26.5''$)

342 The granitic gneiss sample JA1 has stubby to elongated zircon grains (70–200 μm in
343 size). Most zircon grains show a core-rim structure with a weakly patchy zoned core and bright
344 structureless rims (Fig. 7c), suggesting that the zircon cores are magmatic but underwent
345 significant Pb-loss after their crystallization. All analyzed zircon grains have variable Th (71–
346 689 ppm) and U (154.19–1489.30 ppm) contents with Th/U ratio of 0.14–0.77, similar to
347 magmatic zircon (Hoskin and Schaltegger, 2003). Thirty-four analyses were conducted on 32
348 representative zircon grains. Twenty-four zircon spot analyses yield an upper intercept date of
349 2869 ± 17 Ma ($n = 24$, MSWD = 2.5) and a lower intercept date of 675 ± 35 Ma (Fig. 7g). The
350 2869 ± 19 Ma date is interpreted as the crystallization age of the granitic gneiss protolith. The
351 older core analysis (spot Zr22c) yields a $^{207}\text{Pb}/^{206}\text{Pb}$ inherited date of 2901 ± 23 Ma (101% of
352 concordance). Nine remaining discordant spots (Zr3c, Zr9c, Zr16c, Zr19c, Zr24c, Zr28c, Zr29c,
353 Zr32c and Zr37c) were not considered for calculation, owing to their high degree of
354 discordance.

355 5.2.4. Monzogranite (sample U2: $N02^{\circ}22'25.9''/E010^{\circ}20'53.4''$)

356 Sample U2 was collected from a monzogranitic dike that intruded the TTG gneisses
357 (Fig. 2f). Zircon grains from this sample are elongated to stubby and show core-rims structures
358 (Fig. 7d). The cores exhibit magmatic zoning characterised by finely concentric oscillatory
359 zoning with brightness variation in the CL images (Fig. 7d). Some rims show homogeneous
360 structures or blurred zoning, suggesting that the rims are the result of recrystallisation (Fig. 7d).
361 In total, 24 analyses were carried out on 19 zircon grains. They have moderate to high
362 concentration of U (67–754 ppm) and Th (75–468 ppm) with high Th/U ratios from 0.13 to
363 1.53. All the analyzed crystals show a degree of concordance varying between 54 and 98%,
364 regardless of inner and outer parts of the grains, and yielded an upper intercept age of $2881 \pm$

365 15 ($n = 15$, MSWD = 5.8; Supplementary Data, Fig. S3e). Except for spots Zr3c and Zr27c,
366 fifteen analyses of core zircon domains plot along a discordia line and yield an upper intercept
367 age of 2902 ± 18 Ma and lower intercept age of 724 ± 39 Ma ($n = 15/17$, MSWD = 2.6; Fig.
368 7h). Five analyses on the rims yielded an upper intercept age of 2852 ± 31 Ma ($n = 5/7$; MSWD
369 = 2.6, except spot Zr8r and Zr10r1), and a lower intercept date of 528 ± 66 Ma (Fig. 7h).

370 **6. Discussion**

371 *6.1. Significance of the new geochronological data*

372 The rocks of the Ntem Complex have been previously dated to mostly Paleo- to
373 Neoproterozoic ages by using whole-rock Sm-Nd and Rb-Sr isochron techniques, single zircon Pb-
374 Pb evaporation, SHRIMP, SIMS and LA-ICP-MS U-Pb zircon analyses, and monazite EPMA
375 Th-U-Pb analyses (Toteu et al., 1994; Tchameni et al., 2001, 2004; Shang et al., 2004a, 2004b,
376 2010; Takam et al., 2009; Tchameni et al., 2010; Li et al., 2016; Akame et al., 2020a, 2021).
377 Most of these rocks have been affected by multiple geological events/weathering processes,
378 which not only often lead to ambiguity in the interpretation of bulk rock isotope and zircon Pb-
379 Pb evaporation data, but also make it difficult to interpret U-Pb zircon data. Such issues are
380 common in many high-grade Archean terrains, which have usually been affected by a complex
381 magmatic-metamorphic and/or crustal reworking history (e.g. Bauer et al., 2017; Kaur et al.,
382 2019). Thus, the integration of field relationships with petrographically characterised granitoids
383 with their zircon microtextural features allows for a better interpretation of the U-Pb dates
384 obtained in this study.

385 Zircons from the charnockite (JA12), TTG gneiss (JA11), and granitic gneiss (JA1) from
386 the Nyabessane region exhibit core-rim structures with growth or sector zoning and have high
387 Th/U > 0.1, indicating a magmatic origin (Wu and Zheng, 2004; Zheng et al., 2022). As
388 mentioned above, most zircon rims give ages similar to the cores in each sample studied
389 (Supplementary Data, Table S1). This would suggest that most zircons were not recrystallized
390 during later events. Therefore, the ages calculated using core and rim data are considered as the

391 crystallization ages of these samples. Nevertheless, the zircon grains Zr6 and Zr38 for
392 charnockite (sample JA12), and Zr3 for TTG gneiss (sample JA11) display weakly zoning,
393 outer overgrowth, convoluted and thickened bands, suggesting strong recrystallization in these
394 zircons (Corfu, 2003; Rubatto, 2017; Zheng et al., 2022).

395 **Charnockites** –. Most of the dated zircons from sample JA12 are concordant to nearly
396 concordant (Fig.7e), and yield an upper intercept date of 2910 ± 11 Ma, which we interpret as
397 the crystallization age of the charnockite. Our new LA - ICP-SF-MS U-Pb age of 2910 ± 11 is
398 comparable with the SIMS U-Pb zircon crystallization age of 2918 ± 9 Ma for charnockite in
399 Menguémé area (Li et al., 2016; Fig.1), and within errors with the oldest single zircon Pb–Pb
400 evaporation age of 2912 ± 25 Ma reported by Pouclet et al. (2007) for other charnockites from
401 the Ntem Complex. However, two younger crystallization ages of 2883 ± 11 Ma (SHRIMP
402 zircon U-Pb; Takam et al., 2009), and 2850 ± 9 Ma (LA-ICP-MS U-Pb; Akame et al., 2020a)
403 for charnockite respectively in Akom Bikak charnockite and Meyomessi area, have also been
404 reported. Altogether, these geochronological data suggest that there were several separate
405 episodes of charnockitic magmatism in the Ntem complex between ca. 2.95 and 2.85 Ga. The
406 older zircons with $^{207}\text{Pb}/^{206}\text{Pb}$ ages from 3024 Ma to 3121 Ma are interpreted as inherited (Fig.
407 7e). A single concordant date of 2839 ± 24 Ma from a zircon from the sample JA12 is
408 significantly younger than the charnockite emplacement age of the Ntem Complex (2.92–2.85
409 Ga; Takam et al., 2009; Li et al., 2016; Akame et al., 2020a), but close to the timing of high-
410 grade metamorphism event (D1/M1) dated at 2843–2820 Ma in the Sangmelima area (Akame
411 et al., 2020a, 2021). The second youngest core (spot Zr38c2) is a recrystallized rim and its
412 $^{207}\text{Pb}/^{206}\text{Pb}$ age of 2733 ± 29 Ma is interpreted to reflect Neoproterozoic anatexis or
413 metamorphism event in the Nyabessane area. This age is close to the time of Neoproterozoic thermal
414 event (2.76–2.73 Ga) in the Ntem Complex (Akame et al., 2020a, 2021).

415 ***TTG and granitic gneisses*** –. Considering the magmatic zircon-like internal structures and
416 moderate to high Th/U ratios, the upper intercept dates of 2870 ± 8 Ma and 2869 ± 17 Ma
417 obtained on oscillatory-zoned zircon grains from the TTG gneiss (JA11) and granitic gneiss
418 (JA1) respectively of the Nyabessane region are interpreted as their magmatic crystallization
419 ages (Fig. 7f-g). These ages are similar within errors with the SIMS zircon age of 2868 ± 9 Ma
420 reported by Li et al. (2016) for the Djoum trondhjemite (Fig. 1a), whereas the weighted mean
421 $^{207}\text{Pb}/^{206}\text{Pb}$ date of 2865 ± 5 Ma for the TTG gneisses is identical to a SHRIMP zircon age of
422 2865 ± 4 Ma obtained for the Ngoulemakong Tonalite (Tchameni et al., 2010). More recently,
423 EPMA Th–U–total Pb monazite analyses yielded emplacement ages between 2874 and 2860
424 Ma for the Sangmelima TTG (Akame et al., 2021). In addition, field observations indicate that
425 the granitic gneisses do not postdate the TTG gneisses and they were both intruded by later
426 potassic granites before the regional deformation event (D1/M1). The range of ages of 2870–
427 2865 Ma for the TTG gneisses and 2869 ± 17 Ma for granitic gneisses in the Nyabessan area
428 are consistent with these observations (Fig. 1b). Therefore, the Nyabessane TTG and granitic
429 gneisses provide evidence for coeval Mesoarchean Na- and K-rich granitoid magmatism in the
430 Ntem Complex at ca. 2.87–2.86 Ga in. This Mesoarchean felsic magmatism was synchronous
431 with the emplacement of a gabbro intrusion (2869 ± 17 Ma) and the protolith of an amphibolite
432 (2862 ± 10 Ma) within the Ntem Complex (Li et al., 2016; Akame et al., 2020a). Analysis of
433 grain 3c at 2760 ± 24 Ma in the TTG gneiss JA11 is significantly younger than its crystallisation
434 age (Fig. 7f), and probably represent a mixed core-rim date or recrystallized zircon.
435 Nonetheless, this date is close to the time of the Neoproterozoic tectonothermal event in the Ntem
436 Complex (2.76–2.74 Ga Ma; Akame et al., 2020a, 2021) and ca. 2.75 Ga major
437 tectonometamorphic event in northern Gabon domain (Thiéblemont et al., 2018).

438 ***Monzogranite*** –. Field relations show that monzogranite dykes intruded the TTG gneisses (Fig.
439 2). The monzogranite dyke exhibits strong deformation fabrics with well-developed foliation

440 parallel to S1 gneissosity in the host rock, and quartz-feldspar microstructures consistent with
441 deformation under high temperature condition of 500–600 °C (Fig. 3g-h; Trouw et al., 2009).
442 This suggest the monzogranite is syn-tectonic and probably emplaced early during D1
443 deformation. Most zircon grains from U2 sample show core and rim structures with oscillatory
444 zoning. We interpret the upper-intercept date of 2902 ± 18 Ma from the zircon core domains as
445 an inherited age from their protolith. Most of the U-Pb analyses (5 on 7 spots) of the rim
446 domains yield an upper-intercept date of 2852 ± 31 Ma (Fig. 7h), interpreted to reflect the time
447 of intrusion of this monzogranite dyke. This age is consistent with the 2853 ± 12 Ma age
448 determined by SHRIMP zircon by Takam et al. (2009) for the Adzap granite (Fig. 1b). Granitic
449 magmatism of the Nyabessane and Adzap is very close within error age to the 2.84–2.82 Ga
450 period of tectonothermal event documented across the Ntem Complex (Thiéblemont et al.,
451 2018; Akame et al., 2020a, 2021). Thus, their ages likely record crustal anatexis initiation
452 during the regional Mesoarchean tectonothermal event.

453 All ca. 2865–2911 Ma samples of this study contain lower intercept ages of ~ 682–625 Ma (Fig.
454 7). These ages cannot be assigned to any known metamorphic event in the Ntem Complex, but
455 may result from multiple Pb loss, mainly during the distant effects of the Pan-African orogeny.

456 In summary, the Archean charnockites, TTG and granitic gneisses formed at ca $2910 \pm$
457 11 Ma, ca. 2870 ± 8 Ma and ca. 2869 ± 17 Ma, respectively, suggest that there were at least two
458 episodes of felsic magmatism event during the Mesoarchean tectonic evolution of the
459 Nyabessane area on the southwestern margin of the Ntem Complex. The syn-tectonic
460 monzogranite with a crystallisation age of 2852 ± 31 Ma is considered as precursor to the crustal
461 anatexis related to a regional tectonothermal event ca. ~ 2.85–2.82 Ga. The late Neoproterozoic
462 tectonothermal event occurred ca. 2760–2730 Ma.

463 **6.2. Assessment of alteration and element mobility**

464 The Nyabessane granitoids have undergone intensive deformation associated with high-
465 grade metamorphism and migmatization, therefore it is necessary to assess the potential

466 mobility of the elements before undertaking petrogenetic and geodynamic characterizations.
467 All the studied granitoid samples are macroscopically devoid of alteration and have low LOI
468 values (0.31–1.57 wt%), and show no significant Ce anomalies (Ce_N/Ce^* (with Ce^* calculated
469 as $(\sqrt{La_N \times Pr_N})$) of 0.96–1.08 (except 3.28 for sample JA22), suggesting no significant
470 weathering after their emplacement (Polat and Hofmann, 2003). Trace or major element
471 mobility can be assessed by plotting all the analyzed elements against zirconium, which is one
472 of the most immobile elements during alteration and metamorphism (Liégeois and Duchesne,
473 1981; Polat and Hofmann, 2003). The Zr content of the samples exhibit good correlations with
474 Hf (Supplementary data Fig. S4), indicating that Hf has not been remobilized either. With the
475 exception of samples JA17 and JA9, all the other TTG gneiss samples define tight linear trends
476 with Zr vs. LREEs (square of correlation coefficient, $R^2 = 0.80$), Zr vs. Nb ($R^2 = 0.70$), Zr vs.
477 Th ($R^2 = 0.63$), Zr vs. Y ($R^2 = 0.58$), and Zr vs. HREEs ($R^2 = 0.57$) (Fig. S4). We interpreted
478 these elements as being quite immobile during post-magmatic events and appropriate to discuss
479 petrogenesis in the following discussion. This may suggest that the elevated HREE (Gd, Dy,
480 Er) and Y of JA9 and Zr of JA17 are likely related to the magmatic fractionation with
481 crystallizing minerals such as monazite or zircon (magmatic processes in TTG gneisses). In
482 contrast, Zr have scattered relationship with LILE (Ba, Rb, K) and Sr (Supplementary data Fig.
483 S4) suggesting that they were affected by secondary processes. Monzogranite dykes show a
484 systematic correlation of Zr with Ba, Sr, Hf and Y (Supplementary data Fig. S4), and have
485 relatively uniform normalized multi-elemental distribution patterns (Fig. 6h), suggesting
486 robustness of trace element signatures in those samples. Although the number of granitic gneiss
487 and charnockite samples are not large enough for a robust assessment of element mobility, their
488 normalized multi-elemental distribution patterns are relatively uniform (Fig. 5b, f).

489 ***6.3. Petrogenesis of NGB granitoids***

490 ***6.3.1. Charnockites***

491 The Nyabessane charnockites exhibit typical igneous rock features and contain a hypersthene–
492 hornblende–clinopyroxene–plagioclase–quartz assemblage (Figs. 2 and 3). This assemblage
493 suggests that the charnockites underwent metamorphism at high-grade granulite facies
494 condition. They are calcic to calc-alkalic, magnesian, metaluminous and have high Na₂O (3.78–
495 4.59 wt.%) with low K₂O/Na₂O (<0.5) ratios and low P₂O₅ (<0.3 wt.%) and SiO₂ 55–60 wt%)
496 (Table 1). These characteristics are consistent with those of typical Archean igneous I-type
497 charnockites (e.g. Frost and Frost, 2008; Zhang et al., 2014; Zhao et al., 2023). They display
498 high MgO (≥4 wt.%) with Mg# >50, high Cr and Ni and low SiO₂ (55–60 wt.%), and display
499 typical adakitic geochemical affinity (Figs. 5c, 8b, and 9e-f; Drummond and Defant, 1990;
500 Martin et al., 2005; Wang et al., 2006). High MgO, Ni, Cr, and Co contents and Mg# values
501 suggest the involvement of mantle materials in their parental magma (Fig. 9a, g, h; Smithies,
502 2000; Rapp et al., 2010; Laurent et al., 2014; Ge et al., 2018). Furthermore, in the La_N vs.
503 MgO+FeOt and Nb+Zr+Y vs. MgO+FeOt diagram (Fig. 9g, h; , NGB charnockites plot within
504 the mantle array (Laurent et al., 2014). However, elevated MgO, FeOt, Ni, Co, V and Cr
505 contents may be linked to abundant ferromagnesian minerals due to loss of leucosomes as a
506 result of anatexis, rather than the contribution of mantle peridotites in their magma source. In
507 an Al₂O₃/(FeOt + MgO)–(3CaO)–(5K₂O/Na₂O) ternary diagram (Fig. 8a), NGB charnockites
508 plot on the field of low- to high-K mafic melts derived, suggesting that mafic crust was a major
509 source (Laurent et al., 2014). The presence of old xenocryst zircon grains (~ 3020 to 3121 Ma,
510 Fig. 7e) is highlighting the contribution of older felsic crust to their formation. The high Sr and
511 Eu contents without significant Eu anomalies suggest either little contributions of plagioclase
512 in the residue or a lack of its fractionation. Negative Nb and Ti anomalies suggest that Ti-
513 bearing minerals such as rutile were a residual phase. Given their variable Ce/Sr, Sr/Y, La/Y
514 and (La/Yb)_N ratios (Fig. 8c-d and 9b-c-d), the NGB charnockites might have formed at a
515 transitional pressure with garnet-bearing amphibolite as residues (Foley et al., 2002; Moyen,

516 2011). To sum up, we suggest that the charnockites in the NGB were generated mainly by the
517 partial melting of a mixed source comprising both early mafic and ancient felsic crustal
518 materials, consistent with other Mesoarchean charnockites from the Ntem Complex (Shang et
519 al., 2004a; Pouclet et al., 2007; Takam et al., 2009; Li et al., 2016; Akame et al., 2020a).

520 **Fig.8**

521 **6.3.2. TTG gneisses (ca. 2870–2865 Ma)**

522 The Mesoarchean TTG gneisses from Nyabessane are silica- and sodic-rich ($\text{SiO}_2 > 60$
523 wt.%, mean ≈ 68 wt.%; $\text{Na}_2\text{O} = 3.19\text{--}5.30$ wt.%, mean ≈ 4.27) with low $\text{K}_2\text{O}/\text{Na}_2\text{O}$ (mean \approx
524 0.62) ratios and exhibit HREE concentrations between the high- and low- HREE Archean
525 TTGs (Figs. 4b and 6c-d; Halla et al., 2017). They show low content of MgO (0.24 – 4.52
526 wt.%, mean ≈ 1.80), Cr (mean ≈ 29.03 ppm) and Ni (mean ≈ 16.95 ppm) with moderated Mg#
527 (21–51) (Table 1; Fig. 5), indicating weak interaction of TTG magma with mantle wedge (e.g.
528 Smithies, 2000; Martin et al., 2005). In Fig. 8a, most of NGB TTG gneiss samples plot within
529 the low- to high-K mafic rock field, suggesting that mafic crust was a major source. They
530 display mixed adakites and melts derived from metabasalt or eclogite geochemical signatures
531 (Figs. 5c, 8b and 9e-f), implying heterogeneous and varying involvement of enriched sources.
532 Furthermore, in the Sr/Y vs. Y and $(\text{La}/\text{Yb})_N$ vs. Yb diagrams, the TTG gneisses plot within the
533 field of Archean TTG/adakites and arc magmas. This chemical diversity of the NGB TTG
534 gneisses reflects melting at different depths or fractional crystallization (Halla et al., 2009;
535 Moyen, 2011; Palin et al., 2016; Johnson et al., 2017; Liou and Guo, 2019; Laurent et al., 2020).
536 Al_2O_3 , Fe_2O_3 , MgO, CaO, TiO_2 , P_2O_5 , Sc, V, Sr, Co and Cr are all negatively correlated with
537 SiO_2 (Figs. 5, S2), implying the fractional crystallization of plagioclase, amphibole, apatite and
538 Fe-oxides. Zirconium, Hf, and LREE decreases with increasing SiO_2 (Supplementary data Fig.
539 S2), suggesting that accessory phases such as zircon and allanite, are also fractionated minerals.
540 It is suggested that melts with garnet fractionation would be characterized by negative
541 relationship between silica contents and Y and HREE contents and a positive relationship with

542 Sr/Y, Dy/Yb and (La/Yb)_N ratios (e.g. Macpherson et al., 2006). However, some of these trends
543 are not observed here (Supplementary data Fig. S4). The TTG gneisses display good linear
544 positive correlation between La/Hf and La/Yb ratios (Fig. 8e) and decreasing Mg# with
545 increasing La/Sm ratios (Fig. 8f). This suggests that fractional crystallization was not a major
546 process compared to petrogenesis through partial melting of a mafic protolith (Schiano et al.,
547 2010). This is also supported by evidence of mafic enclaves within the TTG gneisses (Fig. 2).
548 Therefore, we suggest that the geochemical diversity of NGB TTG gneisses is more likely
549 reflecting their generation by melting of mafic crust at different depths.

550 The Archean TTGs have been historically devised into three groups according to melting
551 depth: low-pressure' (LP-) TTGs (< 1.0 GPa) with a plagioclase-rich and garnet-bearing
552 amphibolite residue; high-pressure (HP-) TTGs (≥1.5 GPa) with a rutile-bearing eclogite
553 residue; and transitional medium-pressure (MP-) TTGs (1.0–1.5 GPa) with variable amounts
554 of plagioclase and garnet in amphibolite residue (Foley et al., 2002; Moyen and Stevens, 2006;
555 Halla et al., 2009; Moyen, 2011; Moyen and Martin, 2012). Most of the TTG gneisses in the
556 NGB show low- to moderate Sr/Y and La/Yb ratios and can be classified as LP/MP- type TTGs
557 (Fig. 9b-c-d), similar to those of Sangmelima (Shang et al., 2004a; Akame et al., 2020a). This
558 indicates that most TTGs from the Ntem complex were likely generated by partial melting at
559 variable depths (<15 kbar, Moyen, 2011). They have high Sr contents and Zr/Sm > 16, Zr/Hf >
560 36 and Dy/Yb > 1.5 ratios, low Y and Yb contents, moderate (Gd/Yb)_N (mean ≈ 3.3) ratios, and
561 variable Eu anomalies reflecting garnet- and amphibole-bearing residues with variable
562 plagioclase contents (Foley et al., 2002; Moyen, 2009, 2011). Lower FeO_t contents and strong
563 depletion in Nb-Ti on primitive-normalized diagram as seen in NGB TTG gneisses (Table 1,
564 Figs. 6d) imply a residual amphibole and titanomagnetite phase (Hastie et al., 2023).
565 Furthermore, most of studied samples tracking closely along the evolutionary trend of partial
566 melting of Archean mafic/tholeiite sources, leaving garnet-bearing amphibolite residues (Fig.

567 8c-d). The positive Eu anomalies of samples JA4 and JA17 ($\text{Eu}/\text{Eu}^* = 1.2\text{-}1.4$) might be
568 reflecting a local plagioclase accumulation or amphibole fractionation during magma evolution
569 (Liou and Guo, 2019).

570 On a Cr–Mg# plot (Fig. 9a), most of the TTG gneiss samples plot within the field of lower
571 crust–derived TTG and experimental TTG melts, suggesting that the NGB TTG gneisses were
572 formed by partial melting of primitive metamafic material at lower crust (Martin et al., 2005;
573 Rapp et al., 2010; Moyen and Martin, 2012). However, LP-MP TTGs can be generated by basalt
574 melting and/or crystallization at upper crust (< 40 km depth; Laurent et al., 2020), or fractional
575 crystallization of primitive melts within the middle crust with plagioclase accumulation
576 (Kendrick et al., 2022). In Ce/Sr–Y and Sr/Y–Y diagrams, melting and/or crystallization of a
577 less evolved parent melts can produce magmas with compositions similar to NGB TTG gneisses
578 (Fig. 9b, c; Laurent et al., 2020), but most NGB TTG samples tracking closely the evolutionary
579 line of fractional crystallization of an early-crystallizing plagioclase and melt in the Sr/Y–La/Yb
580 plot (Fig. 9d; Kendrick et al., 2022). Hence, it is likely that the NGB TTG magmas underwent
581 magmatic differentiation processes during ascent. Except three samples (JA9, JA22, MNN1)
582 with higher Yb > 1.5 ppm than proper TTGs (Moyen, 2011), most of the TTG gneisses, plot
583 within the field of melt derived from partial melting of subducted oceanic slabs and thickened
584 lower crust (Fig. 9e, f; Martin et al., 2005; Wang et al., 2006, 2017; Guo et al., 2017; Li et al.,
585 2023). Furthermore, most samples plot close to the field of melting of enriched-mantle and
586 crust-derived melt in Fig. 9g, h. Therefore, we suggest that the TTG gneisses of Nyabessane
587 were generated by partial melting of hydrated low- to high-K meta-mafic material or thickened
588 lower crust, followed by magmatic differentiation processes during ascent.

589

590 **Fig. 9.**

591

592 **6.3.3. Granitic gneisses (ca. 2869 Ma)**

593 The granitic gneisses in the NGB are characterized by LREE-enriched with fractionated
594 REE patterns ($(La/Yb)_N = 59-131$), low HREE, $Y < 3$ and Yb_N and higher Sr/Y and $(La/Yb)_N$
595 ratio (Fig. 8c-d), LILE-undepleted, Nb- and Ti-depleted on the normalized diagrams (Fig. 6e-
596 f), which are similar to those of average Archean TTGs and adakites (Martin et al., 2005; Moyen
597 and Martin, 2012). However, these granitic gneisses have high SiO_2 (≥ 74 wt%) and K_2O (4.8
598 – 6.1 wt% with $Na_2O/K_2O < 0.85$) and low Al_2O_3 , FeO, MgO, CaO, TiO_2 and P_2O_5 content,
599 belonging to typical Archean hybrid and potassic granitic rocks (Fig. 4c), indicating crustal
600 origin. Furthermore, all the samples plot in the field of melts derived from tonalites and
601 metasedimentary rocks in Fig. 8a (Laurent et al., 2014) . Their typically I-type granitoid
602 character ($A/CNK \leq 1.1$ and low whole-rock zircon saturation temperatures of 747–802 °C;
603 Watson and Harrison, 1983; King et al., 1997; Liégeois et al., 1998 Fig. 4f and 5h), nearly
604 constant Zr/Hf (32–35) ratios (close to the chondritic value of 36.3; Sun and McDonough,
605 1989) and the absence of Al-enriched minerals such as muscovite, cordierite or tourmaline
606 making an igneous felsic source more probable, rather than a granitic melt derived from
607 metasedimentary rocks. This is further supported by moderated Mg# values (37–47). All
608 granitic gneiss samples plot in the field of melt generated by partial melting of metabasaltic and
609 eclogite experimental melts similar to the ~ 2870 Ma TTG gneisses (Figs. 5c and 8b), which
610 suggests the involvement of mafic crust in their petrogenesis. Thus, the granitic gneisses in the
611 NGB could have been derived from the partial melting of enriched source.

612 It has been proposed that most of I-type granitoids were generated either by partial melting
613 of igneous rocks (e.g. Ju et al., 2017; He et al., 2018) or by mixing of melt derived from mantle
614 and crustal materials, associated or otherwise with fractional crystallization (Zhu et al., 2009).
615 In La/Hf–La and Mg#–La/Sm plots (Fig. 8e, f), the NGB granitic gneisses are linearly
616 correlated, indicating a petrogenetic process involving partial melting rather than fractional

617 crystallization (Schiano et al., 2010). The possibility that these granitic gneisses were derived
618 from high temperature fractional crystallization is therefore not appropriate. The high Sr and
619 low Y with high Sr/Y (Fig. 9c) accompanied by positive Sr anomalies (Fig. 6f) and weak
620 negative to positive Eu anomalies could reflect plagioclase accumulation. Moreover, the
621 granitic gneisses in NGB display steep, LREE-undepleted and HREE-depleted patterns with
622 high $(La/Yb)_N$ and low Yb_N (0.77–1.17) (Figs. 6e and 9d), which indicate that the residues were
623 either enriched in garnet or amphibole (e.g. Martin et al., 2005). In Sr/Y–Y and $(La/Yb)_N$ – Yb_N
624 diagrams (Fig. 8c-d), the Mesoarchean NGB granitic gneisses follow closely the evolutionary
625 trend of partial melting in the eclogite-facies suggesting that they were generated in subducted
626 oceanic slab (Drummond and Defant, 1990; Martin et al., 2005) or in the thickened lower crust
627 (Moyen, 2009). However, such magmas could also have been formed by partial melting of
628 metatonalite under fluid absent conditions in lower- to middle crust (Patiño Douce, 1999; Rutter
629 and Wyllie, 1988; Watkins et al., 2007; Kendrick et al., 2022; Fig. 10h). If the ca 2.87 Ga
630 granitic gneisses in NGB were derived from partial melting of TTG rocks, they cannot be coeval
631 with the TTG gneisses at ca 2.87–2.86 Ga and the absence of older sodic TTGs (≥ 2.9 Ga) in
632 the Ntem Complex would make it more complicate. The possibility that these granitic gneisses
633 were derived from partial melting of TTG is therefore precluded. Most of the ~2.88–3.25 Ga
634 charnockites in the Ntem Complex have tonalite to granodiorite composition with low
635 K_2O/Na_2O (~ 0.5 in average) (Toteu et al., 1994; Shang et al., 2004a; Pouclet et al., 2007;
636 Takam et al., 2009; Akame et al., 2020a), which are more likely that the charnockites were the
637 the source for the granitic gneisses rather than the TTGs and metamafic rocks. The occurrence
638 of ~ 2.9 Ga inherited zircons in granitic gneisses further supports the contribution of an older
639 crust (Fig. 7g). We therefore suggest that the granitic gneisses were derived from the intra-
640 crustal melting of a pre-existing crust (e.g., tonalitic composition), and that both the granitic
641 gneisses and coeval TTG gneisses were generated through the same magmatic event at ~ 2.87

642 Ga. According to Laurent et al. (2020), such granitic magmas may represent the upper part of
643 the magma chamber that generated the Nyabessane TTG magmas.

644

645 *6.3.4. Monzogranites (ca. 2852 Ma)*

646 Geochemical differences between monzogranites and granitic gneisses are remarkable.
647 Monzogranites have higher CaO, Co and lower Al₂O₃, MgO, Rb, Nb, and Y contents and higher
648 Sr/Y and La/Yb ratio than the granitic gneisses. In contrast to the granitic gneisses, the majority
649 of monzogranite samples are ferroan and metaluminous (Fig. 4e-f), and exhibit LREE-enriched
650 and HREE-depleted patterns with positive Eu anomalies (Fig. 6g-h). These chemical features
651 are consistent with those of Archean potassic granitoids derived from partial melting of crustal
652 materials (e.g. Patiño Douce, 1999; Laurent et al., 2014; Moyen, 2019; Figs. 8a and 9g-h). As
653 shown in Fig. 8a, the monzogranites in the NGB are more likely granites produced by remelting
654 of metatonalitic rocks. Furthermore, some ~ 2.91 Ga charnockites and ~2.87 Ga TTG gneisses
655 indeed experienced metamorphism and anatexis in Nyabessane and melt pockets with granitic
656 composition can be found in outcrops where the TTG gneisses show in-situ partial melting (Fig.
657 2d-f). Watkins et al. (2007) proposed that the source of melts that generate the late potassic
658 granites in many Archean terranes must have higher K₂O/Na₂O. The Nyabessane charnockites
659 have an average of K₂O/Na₂O = 0.4, whereas the TTG gneisses have an average of K₂O/Na₂O
660 = 0.6. Therefore, we suggest that the Nyabessane monzogranite were likely derived from intra-
661 crustal anatexis of TTG gneisses. The presence of inherited zircons ages > 2.86 Ga in these
662 monzogranites also supports this conclusion. All the monzogranite samples have pronounced
663 positive Eu and Sr anomalies (Fig. 8f), implying melting in the stability field of plagioclase or
664 plagioclase accumulation. Nevertheless, the high content of K-feldspar in these rocks suggests
665 an earlier accumulation of K-feldspar rather than of plagioclase. Their high Sr/Y and La/Yb

666 and negative Nb-Ti-P anomalies on normalized multi-element patterns (Fig. 6h) are most likely
667 inherited from the TTG magma source.

668 **6.4. Tectonic Setting**

669 Previous workers have suggested that the Mesoarchean charnockitic and TTG suites of the
670 Ntem Complex were formed either by the partial melting of a primitive Archean basaltic crust
671 due to a hot subduction slab (Shang et al., 2004a; Pouclet et al., 2007), or by mantle plume
672 activity (Li et al., 2016), and/or subduction-accretion tectonic process (Akame et al., 2020a).
673 As noted above, most of the Mesoarchean charnockites and TTG gneisses in the Nyabessane
674 granite-greenstone terrains were derived from rocks of basaltic composition, whereas the
675 granitic gneisses and monzogranites show evidences of the reworking of an older felsic crust
676 (Fig. 8a). Despite the predominance of TTGs in Nyabessane, both TTG and granitic gneisses
677 were yet surprisingly emplaced synchronously during the same crust-forming event ca. 2.86 –
678 2.91 Ga ago. These coeval magmatism event required tectonic processes that involved the
679 melting of basaltic rocks at different depths to produce the TTG magmas, and the recycling of
680 the crust to generate the granites found in the Nyabessane terrane. Our study indicates that
681 Mesoarchean charnockites and TTG gneisses display mostly calcic- to calc-alkalic and
682 magnesian affinity similar to Cordilleran granitoid-type (Fig. 4e-d, Frost et al., 2001, Frost and
683 Frost, 2008), implying they originated in magmatic arc setting. Additionally, we have shown
684 that the charnockites and TTG gneisses mainly formed by partial melting of hydrated low- to
685 high-K metamafic/thickened lower crust in arcs (Figs. 8 and 9). In the Rb vs. (Nb + Y) and Nb
686 vs. Y granitic tectonic setting discrimination diagrams, most of charnockites and TTG gneisses
687 plot within the volcanic arc granites and arc plutons field (Fig. 10a-b, Pearce et al., 1984;
688 Hildebrand and Whalen, 2014), but the same charnockites and TTG gneisses samples plot away
689 from arc plutons field on the La/Yb vs. Sr/Y and Gd/Yb vs. Sr/Y diagrams (Fig. 10c-d; Sotiriou
690 et al., 2023). Moreover, all the Mesoarchean granitoids from NGB plot in the slab failure
691 plutons field (Fig. 10c-d). These characteristics suggest that most of Mesoarchean granitoids

692 from NGB may have formed from a long process of partial melting occurring in arc and slab
693 failure scenarios (Hildebrand and Whalen, 2014). Li et al. (2016) proposed that the mantle-
694 plume related to vertical tectonics is the most suitable mechanism to explain Mesoarchean
695 voluminous charnockitic magmatism in the Ntem Complex. However, such hypothesis requires
696 that the conductive heat of the mantle plume induced partial melting of the mafic protocrust,
697 leading to the formation of widespread charnockites and TTG magmas from 2.91 to 2.86 Ga.
698 This also implies the existence of Mesoarchean komatiite lavas in NW Congo Craton
699 (Tomlinson and Condie, 2001). Such a komatiitic magmatism is yet to be found but could have
700 likely occurred in the Ntem Complex. Furthermore, numerous mafic dykes have been identified
701 locally in the NGB (field observations), possibly indicating the existence of mantle plume
702 related magmatism in this region. However, all these mafic to ultramafic rocks have not yet
703 been investigated. In addition, Miocevic et al. (2022) suggested that a vertical tectonic regime
704 related to a mantle plume were not responsible for the generation of Archean TTGs. The
705 possibility that these charnockites and TTGs are the result of partial melting induced by mantle
706 plume activity remains unresolved.

707 The charnockites and TTG gneisses of the Nyabessane area have similar chemical
708 compositions to that of the global LP– MP TTGs (Moyen, 2011), as well as the ca. 2.9 Ga
709 charnockites and ca. 2.86–2.87 Ga TTG suites from the other area of Ntem Complex (Figs. 9b-
710 c-g; Shang et al., 2004a; Pouclet et al., 2007; Akame et al., 2020a), suggesting that they were
711 probably formed at the base of either a thickened felsic crust or an oceanic plateau. However,
712 Ge et al. (2022) suggested that the LP and MP TTGs could be produced by water-fluxed melting
713 of thick oceanic arc crust in subduction–accretion tectonic settings. It is assumed that Archean
714 TTG magmas formed in an arc setting would be characterized by Nb/Nb* and Pb/Pb* anomaly
715 ratios of respectively <1 and >1 (Hofmann, 1997; Zheng, 2019; Windley et al., 2021; Sotiriou
716 et al., 2023). Most of charnockites, TTG and granitic gneisses from the NGB have Nb/Nb*<1

717 and $Pb/Pb^* > 1$ (except sample JA9 and MNN1 with $Pb/Pb^* < 1$) ratios and plot within arc-related
718 fields in Fig. 10e (Sotiriou et al., 2023), suggesting that they were likely generated in
719 subduction-related arc setting. This is also supported by the higher Th/Yb, Th/Nb and Nb/Yb
720 ratios, and pronounced positive Pb and negative Nb and Ti anomalies in primitive mantle-
721 normalised trace element patterns of ca 2.91–2.86 granitoids from the Nyabessane granite-
722 greenstone belt (Figs. 6 and 10f; Sun and McDonough, 1989; Pearce, 2008; Smithies et al.,
723 2018). Similarly to TTG rocks, the ca. 2.87 Ga granitic gneisses display typically arc signature
724 (Figs. 8c-b), but they plot along hybrid melt between the volcanic arc granite and syn-collisional
725 granite field in Fig. 10a). This is consistent with their formation in a transitional tectonic regime
726 involving both subduction and collision. Arc-related magmatism in the NW Congo Craton has
727 widely been reported during the Mesoarchean (Shang et al., 2004a; Pouclet et al., 2007; Akame
728 et al., 2020a; Loemba et al., 2023). Based on the above trend, we suggest that the partial melting
729 of the hydrated low- to high-K metamafic/thickened lower crust as well as the felsic older crust
730 in a subduction-accretion tectonic regime could have generated a large volume of charnockites,
731 TTG and both granitic magmas in the Nyabessane terrane from 2.91 to 2.86 Ga

732 The geochemical data of Nyabessane monzogranitic rocks show that they are
733 compositionally similar to volcanic arc granites (Fig. 10a), thereby suggesting the involvement
734 of a mafic component in their petrogenesis, like those of the TTG gneiss magma source (Fig.
735 8b). However, field relationships and microstructures indicate that the NGB monzogranites are
736 syn-tectonic granitoids (Figs. 2 and 3) and are coeval with a long-lasting regional crustal
737 shortening and magmatic accretion (Ntomba et al., 2020). If the source of the monzogranites
738 were TTG-type rocks, their geochemical features would possibly mirror those from their source
739 or tectonic setting. Thus, the Nyabessane monzogranitic melts (~2852 Ma) might have resulted
740 from crustal anatexis followed by crustal shortening and thickening in response to a high
741 geothermal gradient that prevailed during the Archean. As a whole, the Nyabessane granite-

742 greenstone terrane is geologically similar to the Sangmelima granite-greenstone terrane in the
743 north-eastern of Ntem Complex (Shang et al., 2004a, 2004b, 2007, 2010; Akame et al., 2020a,
744 2020b, 2021), which is also proposed to have been formed during combined subduction and
745 accretion between 3.2 and 2.85 Ga (Akame et al., 2020a). Older, 3.02 to 3.12 Ga inherited
746 zircon grains are found in the NGB charnockites, and they are regarded as vestiges of early
747 Mesoarchean crust or plutonism in these areas of the Ntem Complex. Data hence suggest that
748 the Nyabessane granitoids were formed during a transitional tectonic regime, involving
749 subduction and accretion. In addition, this study supports the reworking of the continental crust
750 in the Ntem Complex prior to ca. 2.87 Ga.

751 The tectonic evolution of the Nyabessane area can be summarized as follows: from 2.92
752 Ga to 2.86 Ga magmas were generated by partial melting of hydrated low- to high-K
753 metamafic/thickened lower crust as well as the intra-crustal felsic proto-crust in a subduction-
754 accretion tectonic setting. Such intrusion later underwent partial melting to form the parental
755 magma of the charnockites, TTG and granitic gneisses. At ~ 2.85 Ga, crustal shortening and
756 anatexis generated the monzogranitic melts followed by high-grade metamorphism at ~ 2.84
757 Ga. Finally, a Neoproterozoic tectonothermal event occurred at ~ 2.76–2.73 Ga, but it was not
758 studied here.

759 **6.5. Implications for the regional geodynamic evolution**

760 The geochemical, and geochronological data presented in this study give new constraints
761 on the geodynamic evolution of the NW Congo Craton and at a broader scale on the associated
762 regimes that prevailed during the Meso- and Neoproterozoic (~ 3.2–2.5 Ga). Numerous studies
763 have proposed that the Earth underwent profound geodynamic changes during the late Archean
764 which may represent a change from early stagnant-lid/plume tectonics to more mobile,
765 subduction-driven plate tectonic processes (Herzberg et al., 2010; Debaille et al., 2013; Cawood
766 et al., 2018; Hawkesworth et al., 2020; Palin et al., 2020; Windley et al., 2021; Sotiriou et al.,
767 2023; Hastie et al., 2023). Such secular change is further endorsed by the rapid development of

768 diverse Meso- to Neoproterozoic high-K granitoids (e.g., sanukitoids, high-K granites, alkaline
769 granites and syenites; e.g. Laurent et al., 2014; Halla et al., 2017), decreasing production of
770 sodic granitoids (TTGs) and komatiites (Moyen and Martin, 2012; Hoffmann et al., 2019), and
771 increasing degree of crustal recycling as well as the emergence of late Archean paired
772 metamorphic belts (Laurent et al., 2014; Dhuime et al., 2018; Cawood et al., 2018; Brown et
773 al., 2020). In this scenario, the Ntem Complex appears to have a geological record that
774 resembles such changes observed in other cratons worldwide. The recent compiled
775 geochronological and geochemical dataset of the Ntem Complex reveal an evolution of the
776 granitoid compositions from ca 3.2 to 2.5 Ga, with the emplacement of voluminous charnockitic
777 to TTG magmas ~3.15–2.85 Ga ago as well as high-K granitoids around ~2.75–2.66 Ga (Akame
778 et al., 2023). Recently, ca. 2.9 Ga magmatic rocks were identified using LA-ICP MS methods
779 from four outcrops of the Ayina Group (Fig. 1b; Toteu et al., 2022). The association of ~ 2.87
780 Ga high-K granite and TTG gneisses in the Nyabessane terrane might likely reflect that the
781 high-K magmatism started coevally with crustal growth in the Ntem complex. The ca. 2.91 Ga
782 Menguémé charnockite in the north-eastern of Ntem Complex and ca 2.89 Ivondo Complex
783 TTGs in the northern part of the Republic of Congo were considered to have been formed by
784 partial melting of mafic rocks and preexisting Paleoproterozoic crust, possibly triggered by mantle
785 upwelling or plume activity (Li et al., 2016; Gatsé Ebotehouna et al., 2021). As documented
786 above, the basement of the Mesoproterozoic granitoids of the NW Congo craton were likely mainly
787 formed by the partial melting of hydrated low- to high-K metamafic/thickened lower crust in
788 subducted-related setting, while the remelting of pre-existing crustal materials of different
789 sources was involved in the crust-building process. These rocks record prolonged late Meso- to
790 Neoproterozoic crust-mantle geodynamic processes probably related to oceanic subduction and
791 continental accretion. Nevertheless, as mentioned above the possibility of the occurrence of

792 plume-related setting is not excluded, and further field investigation within the NW Congo
793 Craton has the potential to better constrain this issue.

794 The regional Mesoarchean metamorphic event occurred at ca 2.84–2.82 Ga in the NW
795 Congo Craton (Thiéblemont et al., 2018; Akame et al., 2020a, 2021; Loemba et al., 2023). This
796 event is temporarily close to the diatexitic migmatite of granitic composition from the
797 Sangmelima area (2843 ± 7 Ma), which is interpreted as a result of the partial melting of older
798 TTGs at in the lower crust, reflecting crustal thickening caused by continental collision (Akame
799 et al., 2020a). Consequently, the occurrence of high-K granitoids at 2.85 Ga, and the subsequent
800 metamorphic event at ca. 2.84 Ga in the Ntem Complex, might reflect the geodynamic transition
801 from vertical processes to horizontal subduction/accretion processes with small involvement of
802 mantle-derived melts (e.g. Palin et al., 2020; Windley et al., 2021).

803 **7. Conclusions**

804 Diverse Mesoarchean granitoids occur in the Nyabessane granite-greenstone terrane
805 (NGB), part of the Ntem Complex in the Northwest Congo Craton. They are charnockites, TTG
806 gneisses and granitic gneisses dated at $\sim 2910 \pm 11$ Ma, $\sim 2870 \pm 8$ Ma, and $\sim 2869 \pm 17$ Ma,
807 respectively by zircon U-Pb LA-SF-ICP-MS. The anatexis of TTG gneisses were generated the
808 monzogranites at ca. 2852 ± 31 Ma, followed by intensive regional deformation and
809 metamorphism associated with migmatization at ~ 2.84 – 2.82 Ga and ~ 2.76 – 2.72 Ga. The 2.91–
810 2.86 Ga granitoids include charnockites, TTG and granitic gneisses generated by partial melting
811 of hydrated low- to high-K metamafic/thickened lower crust as well as the intra-crustal felsic
812 proto-crust in a subduction-accretion tectonic setting and were then emplaced to form the
813 parental magma of the charnockites, TTG and granitic gneisses. The geochemical diversity of
814 the TTG gneisses may reflect melting source at various depths followed by magmatic
815 differentiation during ascent. The occurrence of high-K granitoids at 2.85 Ga and the
816 subsequent metamorphic event at ca. 2.84 Ga in the Ntem Complex, might reflect geodynamic
817 regime transition from vertical processes to horizontal subduction-accretion processes with

818 minor involvement of mantle-derived melts. This process, combined with multiple re-melting
819 of existing crust, progressively contributed to the maturation and stabilisation of the continental
820 crust in the Congo Craton.

821

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831 **References**

- 832 Akame, J.M., Debaille, V., Poujol, M., 2023. Combined bulk-rock Lu-Hf and Sm-Nd isotopic
833 study of Archean granitoids and mafic rocks from Sangmelima terranes (Ntem
834 Complex, south Cameroon): Geodynamic implications. *Precambrian Research* 392,
835 107072. <https://doi.org/10.1016/j.precamres.2023.107072>
- 836 Akame, J.M., Oliveira, E.P., Poujol, M., Hublet, G., Debaille, V., 2020a. LA–ICP–MS zircon
837 U Pb dating, Lu Hf, Sm Nd geochronology and tectonic setting of the Mesoarchean
838 mafic and felsic magmatic rocks in the Sangmelima granite-greenstone terrane, Ntem
839 Complex (South Cameroon). *Lithos* 372–373, 105702.
840 <https://doi.org/10.1016/j.lithos.2020.105702>
- 841 Akame, J.M., Owona, S., Hublet, G., Debaille, V., 2020b. Archean tectonics in the
842 sangmelima granite-greenstone terrains, Ntem Complex (NW Congo craton), southern

843 Cameroon. *Journal of African Earth Sciences* 168, 103872.
844 <https://doi.org/10.1016/j.jafrearsci.2020.103872>

845 Akame, J.M., Schulz, B., Owona, S., Debaille, V., 2021. Monazite EPMA-CHIME dating of
846 Sangmelima granulite and granitoid rocks in the Ntem Complex, Cameroon:
847 Implications for Archean tectono-thermal evolution of NW Congo craton. *Journal of*
848 *African Earth Sciences* 181, 104268. <https://doi.org/10.1016/j.jafrearsci.2021.104268>

849 Anders, E., Grevesse, N., 1989. Abundances of the elements: Meteoritic and solar.
850 *Geochimica et Cosmochimica Acta* 53, 197–214. [https://doi.org/10.1016/0016-](https://doi.org/10.1016/0016-7037(89)90286-X)
851 [7037\(89\)90286-X](https://doi.org/10.1016/0016-7037(89)90286-X)

852 Barker, F., 1979. Trondhjemite: Definition, Environment and Hypotheses of Origin, in:
853 *Developments in Petrology*. Elsevier, pp. 1–12. [https://doi.org/10.1016/B978-0-444-](https://doi.org/10.1016/B978-0-444-41765-7.50006-X)
854 [41765-7.50006-X](https://doi.org/10.1016/B978-0-444-41765-7.50006-X)

855 Batchelor, R.A., Bowden, P., 1985. Petrogenetic interpretation of granitoid rock series using
856 multicationic parameters. *Chemical Geology* 48, 43–55. [https://doi.org/10.1016/0009-](https://doi.org/10.1016/0009-2541(85)90034-8)
857 [2541\(85\)90034-8](https://doi.org/10.1016/0009-2541(85)90034-8)

858 Bauer, A.M., Fisher, C.M., Vervoort, J.D., Bowring, S.A., 2017. Coupled zircon Lu–Hf and
859 U–Pb isotopic analyses of the oldest terrestrial crust, the >4.03 Ga Acasta Gneiss
860 Complex. *Earth and Planetary Science Letters* 458, 37–48.
861 <https://doi.org/10.1016/j.epsl.2016.10.036>

862 Bédard, J.H., 2018. Stagnant lids and mantle overturns: Implications for Archaean tectonics,
863 magmagenesis, crustal growth, mantle evolution, and the start of plate tectonics.
864 *Geoscience Frontiers* 9, 19–49. <https://doi.org/10.1016/j.gsf.2017.01.005>

865 Boehnke, P., Watson, E.B., Trail, D., Harrison, T.M., Schmitt, A.K., 2013. Zircon saturation
866 re-revisited. *Chemical Geology* 351, 324–334.
867 <https://doi.org/10.1016/j.chemgeo.2013.05.028>

868 Brown, M., Johnson, T., Gardiner, N.J., 2020. Plate Tectonics and the Archean Earth. *Annu.*
869 *Rev. Earth Planet. Sci.* 48, 291–320. <https://doi.org/10.1146/annurev-earth-081619->
870 052705

871 Cawood, P.A., Hawkesworth, C.J., Pisarevsky, S.A., Dhuime, B., Capitanio, F.A., Nebel, O.,
872 2018. Geological archive of the onset of plate tectonics. *Phil. Trans. R. Soc. A.* 376,
873 20170405. <https://doi.org/10.1098/rsta.2017.0405>

874 Chen, Q., Sun, M., Zhao, G., Zhao, J., Zhu, W., Long, X., Wang, J., 2019. Episodic crustal
875 growth and reworking of the Yudongzi terrane, South China: Constraints from the
876 Archean TTGs and potassic granites and Paleoproterozoic amphibolites. *Lithos* 326–
877 327, 1–18. <https://doi.org/10.1016/j.lithos.2018.12.005>

878 Chombong, N.N., Suh, C.E., 2013. 2883 Ma commencement of BIF deposition at the northern
879 edge of Congo craton, southern Cameroon: new zircon SHRIMP data constraint from
880 metavolcanics. *Episodes* 36, 47–57.

881 Condie, K.C., 2005. TTGs and adakites: are they both slab melts? *Lithos* 80, 33–44.
882 <https://doi.org/10.1016/j.lithos.2003.11.001>

883 Condie, K.C., Bowling, G.P., Allen, P., 1985. Missing Eu anomaly and Archean high-grade
884 granites. *Geol* 13, 633. <https://doi.org/10.1130/0091->
885 7613(1985)13<633:MEAAAH>2.0.CO;2

886 Corfu, F., 2003. Atlas of Zircon Textures. *Reviews in Mineralogy and Geochemistry* 53, 469–
887 500. <https://doi.org/10.2113/0530469>

888 Debaille, V., O'Neill, C., Brandon, A.D., Haenecour, P., Yin, Q.-Z., Mattielli, N., Treiman,
889 A.H., 2013. Stagnant-lid tectonics in early Earth revealed by ¹⁴²Nd variations in late
890 Archean rocks. *Earth and Planetary Science Letters* 373, 83–92.
891 <https://doi.org/10.1016/j.epsl.2013.04.016>

892 Debon, F., Fort, P.L., 1983. A chemical–mineralogical classification of common plutonic
893 rocks and associations. *Earth and Environmental Science Transactions of The Royal*
894 *Society of Edinburgh* 73, 135–149. <https://doi.org/10.1017/S0263593300010117>

895 Deng, H., Kusky, T., Polat, A., Wang, C., Wang, L., Li, Y., Wang, J., 2016. A 2.5 Ga fore-arc
896 subduction-accretion complex in the Dengfeng Granite-Greenstone Belt, Southern
897 North China Craton. *Precambrian Research* 275, 241–264.
898 <https://doi.org/10.1016/j.precamres.2016.01.024>

899 Dhuime, B., Hawkesworth, C.J., Delavault, H., Cawood, P.A., 2018. Rates of generation and
900 destruction of the continental crust: implications for continental growth. *Phil. Trans.*
901 *R. Soc. A.* 376, 20170403. <https://doi.org/10.1098/rsta.2017.0403>

902 Dickinson, W.R., Gehrels, G.E., 2003. U–Pb ages of detrital zircons from Permian and
903 Jurassic eolian sandstones of the Colorado Plateau, USA: paleogeographic
904 implications. *Sedimentary Geology* 163, 29–66.

905 Drummond, M.S., Defant, M.J., 1990. A model for trondhjemite-tonalite-dacite genesis and
906 crustal growth via slab melting: Archean to modern comparisons. *Journal of*
907 *Geophysical Research: Solid Earth* 95, 21503–21521.

908 Foley, S., Tiepolo, M., Vannucci, R., 2002. Growth of early continental crust controlled by
909 melting of amphibolite in subduction zones. *Nature* 417, 837.

910 Frost, B.R., Barnes, C.G., Collins, W.J., Arculus, R.J., Ellis, D.J., Frost, C.D., 2001. A
911 geochemical classification for granitic rocks. *Journal of petrology* 42, 2033–2048.

912 Frost, B.R., Frost, C.D., 2008. On charnockites. *Gondwana Research* 13, 30–44.
913 <https://doi.org/10.1016/j.gr.2007.07.006>

914 Gatsé Ebotehouna, C., Xie, Y., Adomako- Ansah, K., Qu, Y., 2021. Petrology, geochemistry,
915 and zircon U–Pb- LU–HF isotopes of granitoids from the Ivindo Basement Complex

916 of the Souanké Area, Republic of Congo: Insights into the evolution of Archean
917 continental crust. *Geological Journal* 56, 4861–4887. <https://doi.org/10.1002/gj.4219>

918 Ge, R., Wilde, S.A., Zhu, W., Zhou, T., Si, Y., 2022. Formation and evolution of Archean
919 continental crust: A thermodynamic – geochemical perspective of granitoids from the
920 Tarim Craton, NW China. *Earth-Science Reviews* 234, 104219.
921 <https://doi.org/10.1016/j.earscirev.2022.104219>

922 Ge, R., Zhu, W., Wilde, S.A., Wu, H., 2018. Remnants of Eoarchean continental crust derived
923 from a subducted proto-arc. *Sci. Adv.* 4, eaao3159.
924 <https://doi.org/10.1126/sciadv.aao3159>

925 Guo, B., Liu, S., Santosh, M., Wang, W., 2017. Neoproterozoic arc magmatism and crustal
926 growth in the north-eastern North China Craton: Evidence from granitoid gneisses in
927 the Southern Jilin Province. *Precambrian Research, Archean to Proterozoic Evolution*
928 of the North China Craton 303, 30–53.
929 <https://doi.org/10.1016/j.precamres.2016.12.009>

930 Halla, J., van Hunen, J., Heilimo, E., Hölttä, P., 2009. Geochemical and numerical constraints
931 on Neoproterozoic plate tectonics. *Precambrian Research* 174, 155–162.
932 <https://doi.org/10.1016/j.precamres.2009.07.008>

933 Halla, J., Whitehouse, M.J., Ahmad, T., Bagai, Z., 2017. Archean granitoids: an overview
934 and significance from a tectonic perspective. *Geological Society, London, Special*
935 *Publications* 449, 1–18.

936 Hastie, A.R., Fitton, J.G., Bromiley, G.D., Butler, I.B., Odling, N.W.A., 2016. The origin of
937 Earth's first continents and the onset of plate tectonics. *Geology* 44, 855–858.
938 <https://doi.org/10.1130/G38226.1>

939 Hastie, A.R., Law, S., Bromiley, G.D., Fitton, J.G., Harley, S.L., Muir, D.D., 2023. Deep
940 formation of Earth's earliest continental crust consistent with subduction. *Nat. Geosci.*
941 16, 816–821. <https://doi.org/10.1038/s41561-023-01249-5>

942 Hawkesworth, C.J., Cawood, P.A., Dhuime, B., 2020. The Evolution of the Continental Crust
943 and the Onset of Plate Tectonics. *Front. Earth Sci.* 8, 326.
944 <https://doi.org/10.3389/feart.2020.00326>

945 He, X., Zhong, H., Zhao, Z., Tan, S., Zhu, W., Yang, S., Hu, W., Tang, Z., Bao, C., 2018. U-
946 Pb Geochronology, Elemental and Sr-Nd Isotopic Geochemistry of the Houyaoyu
947 Granite Porphyries: Implication for the Genesis of Early Cretaceous Felsic Intrusions
948 in East Qinling. *J. Earth Sci.* 29, 920–938. <https://doi.org/10.1007/s12583-018-0788-2>

949 Herzberg, C., Condie, K., Korenaga, J., 2010. Thermal history of the Earth and its
950 petrological expression. *Earth and Planetary Science Letters* 292, 79–88.

951 Hildebrand, R.S., Whalen, J.B., 2017. The Tectonic Setting and Origin of Cretaceous
952 Batholiths within the North American Cordillera: The Case for Slab Failure
953 Magmatism and Its Significance for Crustal Growth, in: Hildebrand, R.S., Whalen,
954 J.B. (Eds.), *The Tectonic Setting and Origin of Cretaceous Batholiths within the North
955 American Cordillera: The Case for Slab Failure Magmatism and Its Significance for
956 Crustal Growth*. Geological Society of America, p. 0.
957 <https://doi.org/10.1130/2017.2532>

958 Hildebrand, R.S., Whalen, J.B., 2014. Arc and Slab-Failure Magmatism in Cordilleran
959 Batholiths II – The Cretaceous Peninsular Ranges Batholith of Southern and Baja
960 California. *GS* 41, 399. <https://doi.org/10.12789/geocanj.2014.41.059>

961 Hoffmann, J.E., Zhang, C., Moyen, J.-F., Nagel, T.J., 2019. Chapter 7 - The Formation of
962 Tonalites–Trondjhemite–Granodiorites in Early Continental Crust, in: Van
963 Kranendonk, M.J., Bennett, V.C., Hoffmann, J.E. (Eds.), *Earth's Oldest Rocks*

964 (Second Edition). Elsevier, pp. 133–168. [https://doi.org/10.1016/B978-0-444-63901-](https://doi.org/10.1016/B978-0-444-63901-1.00007-1)
965 [1.00007-1](https://doi.org/10.1016/B978-0-444-63901-1.00007-1)

966 Hofmann, A.W., 1997. Mantle geochemistry: the message from oceanic volcanism. *Nature*
967 385, 219–229. <https://doi.org/10.1038/385219a0>

968 Hoskin, P.W., Schaltegger, U., 2003. The composition of zircon and igneous and
969 metamorphic petrogenesis. *Reviews in mineralogy and geochemistry* 53, 27–62.

970 Hughes, C.J., 1972. Spilites, keratophyres, and the igneous spectrum. *Geol. Mag.* 109, 513–
971 527. <https://doi.org/10.1017/S0016756800042795>

972 Jagoutz, O., Schmidt, M.W., Enggist, A., Burg, J.-P., Hamid, D., Hussain, S., 2013. TTG-type
973 plutonic rocks formed in a modern arc batholith by hydrous fractionation in the lower
974 arc crust. *Contrib Mineral Petrol* 166, 1099–1118. [https://doi.org/10.1007/s00410-013-](https://doi.org/10.1007/s00410-013-0911-4)
975 [0911-4](https://doi.org/10.1007/s00410-013-0911-4)

976 Johnson, T.E., Brown, M., Gardiner, N.J., Kirkland, C.L., Smithies, R.H., 2017. Earth's first
977 stable continents did not form by subduction. *Nature* 543, 239–242.
978 <https://doi.org/10.1038/nature21383>

979 Joshi, K., Bhattacharjee, J., Rai, G., Halla, J., Ahmad, T., Kurhila, M., Heilimo, E.,
980 Choudhary, A.K., 2017. The diversification of granitoids and plate tectonic
981 implications at the Archaean–Proterozoic boundary in the Bundelkhand Craton,
982 Central India. *Geological Society, London, Special Publications* 449, 123–157.
983 <https://doi.org/10.1144/SP449.8>

984 Ju, Y., Zhang, X., Lai, S., Qin, J., 2017. Permian–Triassic highly-fractionated I-type granites
985 from the southwestern Qaidam Basin (NW China): Implications for the evolution of
986 the paleo-tethys in the eastern Kunlun orogenic belt. *J. Earth Sci.* 28, 51–62.
987 <https://doi.org/10.1007/s12583-017-0745-5>

988 Kaur, P., Zeh, A., Chaudhri, N., 2019. Archean crustal evolution of the Aravalli Banded
989 Gneissic Complex, NW India: Constraints from zircon U-Pb ages, Lu-Hf isotope
990 systematics, and whole-rock geochemistry of granitoids. *Precambrian Research* 327,
991 81–102. <https://doi.org/10.1016/j.precamres.2019.03.004>

992 Kendrick, J., Duguet, M., Yakymchuk, C., 2022. Diversification of Archean tonalite-
993 trondhjemite-granodiorite suites in a mushy middle crust. *Geology* 50, 76–80.
994 <https://doi.org/10.1130/G49287.1>

995 Kendrick, J., Yakymchuk, C., 2020. Garnet fractionation, progressive melt loss and bulk
996 composition variations in anatectic metabasites: Complications for interpreting the
997 geodynamic significance of TTGs. *Geoscience Frontiers* 11, 745–763.
998 <https://doi.org/10.1016/j.gsf.2019.12.001>

999 King, P.L., White, A.J.R., Chappell, B.W., Allen, C.M., 1997. Characterization and Origin of
1000 Aluminous A-type Granites from the Lachlan Fold Belt, Southeastern Australia.
1001 *Journal of Petrology* 38, 371–391. <https://doi.org/10.1093/petroj/38.3.371>

1002 Kleinhanns, I.C., Kramers, J.D., Kamber, B.S., 2003. Importance of water for Archaean
1003 granitoid petrology: a comparative study of TTG and potassic granitoids from
1004 Barberton Mountain Land, South Africa. *Contributions to Mineralogy and Petrology*
1005 145, 377–389. <https://doi.org/10.1007/s00410-003-0459-9>

1006 Laurent, O., Björnsen, J., Wotzlav, J.-F., Bretscher, S., Pimenta Silva, M., Moyen, J.-F.,
1007 Ulmer, P., Bachmann, O., 2020. Earth’s earliest granitoids are crystal-rich magma
1008 reservoirs tapped by silicic eruptions. *Nature Geoscience* 13, 163–169.
1009 <https://doi.org/10.1038/s41561-019-0520-6>

1010 Laurent, O., Martin, H., Doucelance, R., Moyen, J.-F., Paquette, J.-L., 2011. Geochemistry
1011 and petrogenesis of high-K “sanukitoids” from the Bulai pluton, Central Limpopo

1012 Belt, South Africa: Implications for geodynamic changes at the Archaean–Proterozoic
1013 boundary. *Lithos* 123, 73–91. <https://doi.org/10.1016/j.lithos.2010.12.009>

1014 Laurent, O., Martin, H., Moyen, J.F., Doucelance, R., 2014. The diversity and evolution of
1015 late-Archaean granitoids: Evidence for the onset of “modern-style” plate tectonics
1016 between 3.0 and 2.5Ga. *Lithos* 205, 208–235.
1017 <https://doi.org/10.1016/j.lithos.2014.06.012>

1018 Li, X.H., Chen, Y., Li, J., Yang, C., Ling, X.-X., Tchouankoue, J.P., 2016. New isotopic
1019 constraints on age and origin of Mesoarchean charnockite, trondhjemite and
1020 amphibolite in the Ntem Complex of NW Congo Craton, southern Cameroon.
1021 *Precambrian Research* 276, 14–23. <https://doi.org/10.1016/j.precamres.2016.01.027>

1022 Li, Z., Shan, X., Liu, J., Zhang, J., Liu, Z., Cheng, C., Wang, Z., Zhao, C., Yu, H., 2023. Late
1023 Neoproterozoic TTG and monzogranite in the northeastern North China Craton:
1024 Implications for partial melting of a thickened lower crust. *Gondwana Research* 115,
1025 201–223. <https://doi.org/10.1016/j.gr.2022.10.008>

1026 Liégeois, J.-P., Duchesne, J.-C., 1981. The Lac Cornu retrograded eclogites (Aiguilles Rouges
1027 massif, Western Alps, France): evidence of crustal origin and metasomatic alteration.
1028 *Lithos* 14, 35–48. [https://doi.org/10.1016/0024-4937\(81\)90035-9](https://doi.org/10.1016/0024-4937(81)90035-9)

1029 Liégeois, J.-P., Navez, J., Hertogen, J., Black, R., 1998. Contrasting origin of post-collisional
1030 high-K calc-alkaline and shoshonitic versus alkaline and peralkaline granitoids. The
1031 use of sliding normalization. *Lithos* 45, 1–28. [https://doi.org/10.1016/S0024-4937\(98\)00023-1](https://doi.org/10.1016/S0024-4937(98)00023-1)

1032

1033 Liou, P., Guo, J., 2019. Generation of Archaean TTG Gneisses Through Amphibole-
1034 Dominated Fractionation. *J. Geophys. Res. Solid Earth* 124, 3605–3619.
1035 <https://doi.org/10.1029/2018JB017024>

1036 Loemba, A.P.R., Ferreira, A., Ntsiele, L.J.E.P., Opo, U.F., Bazebizonza Tchiguina, N.C.,
1037 Nkodia, H.M.D.-V., Klausen, M., Boudzoumou, F., 2023. Archean crustal generation
1038 and Neoproterozoic partial melting in the Ivindo basement, NW Congo craton,
1039 Republic of Congo: Petrology, geochemistry and zircon U–Pb geochronology
1040 constraints. *Journal of African Earth Sciences* 200, 104852.
1041 <https://doi.org/10.1016/j.jafrearsci.2023.104852>

1042 Macpherson, C.G., Dreher, S.T., Thirlwall, M.F., 2006. Adakites without slab melting: High
1043 pressure differentiation of island arc magma, Mindanao, the Philippines. *Earth and
1044 Planetary Science Letters* 243, 581–593. <https://doi.org/10.1016/j.epsl.2005.12.034>

1045 Martin, H., 1994. Chapter 6 The Archean Grey Gneisses and the Genesis of Continental
1046 Crust, in: *Developments in Precambrian Geology*. Elsevier, pp. 205–259.
1047 [https://doi.org/10.1016/S0166-2635\(08\)70224-X](https://doi.org/10.1016/S0166-2635(08)70224-X)

1048 Martin, H., 1987. Petrogenesis of Archean Trondhjemites, Tonalites, and Granodiorites from
1049 Eastern Finland: Major and Trace Element Geochemistry. *Journal of Petrology* 28,
1050 921–953. <https://doi.org/10.1093/petrology/28.5.921>

1051 Martin, H., Moyen, J.-F., Guitreau, M., Blichert-Toft, J., Le Pennec, J.-L., 2014. Why
1052 Archean TTG cannot be generated by MORB melting in subduction zones. *Lithos*
1053 198–199, 1–13. <https://doi.org/10.1016/j.lithos.2014.02.017>

1054 Martin, H., Smithies, R.H., Rapp, R., Moyen, J.-F., Champion, D., 2005. An overview of
1055 adakite, tonalite–trondhjemite–granodiorite (TTG), and sanukitoid: relationships and
1056 some implications for crustal evolution. *Lithos* 79, 1–24.
1057 <https://doi.org/10.1016/j.lithos.2004.04.048>

1058 Maurizot, P., Abessolo, A., Feybesse, J.L., Johan, L.P., 1986. Etude et prospection minière du
1059 Sud-Ouest Cameroun, synthèse des travaux de 1978 a 1985. Rapport du BRGM№ 85.

1060 Miocevich, S.R., Copley, A., Weller, O.M., 2022. Testing the importance of sagduction:
1061 insights from the Lewisian Gneiss Complex of northwest Scotland. *Precambrian*
1062 *Research* 379, 106708. <https://doi.org/10.1016/j.precamres.2022.106708>

1063 Moyen, J., Stevens, G., 2006. Experimental constraints on TTG petrogenesis: implications for
1064 Archean geodynamics. *GEOPHYSICAL MONOGRAPH-AMERICAN*
1065 *GEOPHYSICAL UNION* 164, 149.

1066 Moyen, J.-F., 2019. Archean granitoids: classification, petrology, geochemistry and origin.
1067 Geological Society, London, Special Publications SP489-2018–34.
1068 <https://doi.org/10.1144/SP489-2018-34>

1069 Moyen, J.-F., 2011. The composite Archaean grey gneisses: Petrological significance, and
1070 evidence for a non-unique tectonic setting for Archaean crustal growth. *Lithos* 123,
1071 21–36. <https://doi.org/10.1016/j.lithos.2010.09.015>

1072 Moyen, J.-F., 2009. High Sr/Y and La/Yb ratios: The meaning of the “adakitic signature.”
1073 *Lithos*, The genesis and significance of adakitic, high-Mg andesites, and other
1074 refractory magmas in intra-oceanic forearc settings 112, 556–574.
1075 <https://doi.org/10.1016/j.lithos.2009.04.001>

1076 Moyen, J.-F., Laurent, O., 2018. Archaean tectonic systems: A view from igneous rocks.
1077 *Lithos* 302–303, 99–125. <https://doi.org/10.1016/j.lithos.2017.11.038>

1078 Moyen, J.-F., Laurent, O., Chelle-Michou, C., Couzinié, S., Vanderhaeghe, O., Zeh, A.,
1079 Villaros, A., Gardien, V., 2017. Collision vs. subduction-related magmatism: Two
1080 contrasting ways of granite formation and implications for crustal growth. *Lithos*,
1081 Eighth Hutton Symposium on Granites and Related Rocks 277, 154–177.
1082 <https://doi.org/10.1016/j.lithos.2016.09.018>

1083 Moyen, J.-F., Martin, H., 2012. Forty years of TTG research. *Lithos* 148, 312–336.
1084 <https://doi.org/10.1016/j.lithos.2012.06.010>

1085 Nagel, T.J., Hoffmann, J.E., Münker, C., 2012. Generation of Eoarchean tonalite-
1086 trondhjemite-granodiorite series from thickened mafic arc crust. *Geology* 40, 375–
1087 378. <https://doi.org/10.1130/G32729.1>

1088 Ntomba, S.M., Bidzang, F.N., Ottou, J.E.M., Goussi Ngalamo, F.J., Bisso, D., Magnekou
1089 Takamte, C.R., Ondo, J.M., 2016. Phlogopite compositions as an indicator of both
1090 the geodynamic context of granitoids and the metallogeny aspect in Memve'ele
1091 Archean area, northwestern Congo craton. *Journal of African Earth Sciences* 118,
1092 231–244. <https://doi.org/10.1016/j.jafrearsci.2016.02.004>

1093 Ntomba, S.M., Bisso, D., Magnekou Takamte, R.C., Bidzang, F.N., Messi Ottou, E.J., Ondo,
1094 J.M., 2020. Crustal growth in the Mesoarchean plutonic belt from the Memve'ele area
1095 (Ntem Complex-southwestern Cameroon): Evidence of “early earth” transpressional
1096 tectonics. *Journal of Structural Geology* 141, 104195.
1097 <https://doi.org/10.1016/j.jsg.2020.104195>

1098 Nzenti, J.P., Barbey, P., Macaudiere, J., Soba, D., 1988. Origin and evolution of the late
1099 precambrian high-grade Yaounde Gneisses (Cameroon). *Precambrian Research* 38,
1100 91–109. [https://doi.org/10.1016/0301-9268\(88\)90086-1](https://doi.org/10.1016/0301-9268(88)90086-1)

1101 O'Neil, J., Carlson, R.W., 2017. Building Archean cratons from Hadean mafic crust. *Science*
1102 355, 1199–1202. <https://doi.org/10.1126/science.aah3823>

1103 Owona, S., Ondo, J.M., Ratschbacher, L., Ndzana, S.P.M., Tchoua, F.M., Ekodeck, G.E.,
1104 2011. The geometry of the Archean, Paleo- and Neoproterozoic tectonics in the
1105 Southwest Cameroon. *Comptes Rendus Geoscience* 343, 312–322.
1106 <https://doi.org/10.1016/j.crte.2010.12.008>

1107 Owona, S., Ratschbacher, L., Nsangou Ngapna, M., Gulzar, A.M., Mvondo Ondo, J.,
1108 Emmanuel Ekodeck, G., 2021. How diverse is the source? Age, provenance,
1109 reworking, and overprint of Precambrian meta-sedimentary rocks of West Gondwana,

1110 Cameroon, from zircon U-Pb geochronology. *Precambrian Research* 359, 106220.
1111 <https://doi.org/10.1016/j.precamres.2021.106220>

1112 Palin, R.M., Santosh, M., Cao, W., Li, S.-S., Hernández-Uribe, D., Parsons, A., 2020. Secular
1113 change and the onset of plate tectonics on Earth. *Earth-Science Reviews* 207, 103172.
1114 <https://doi.org/10.1016/j.earscirev.2020.103172>

1115 Palin, R.M., White, R.W., Green, E.C.R., 2016. Partial melting of metabasic rocks and the
1116 generation of tonalitic–trondhjemitic–granodioritic (TTG) crust in the Archaean:
1117 Constraints from phase equilibrium modelling. *Precambrian Research* 287, 73–90.
1118 <https://doi.org/10.1016/j.precamres.2016.11.001>

1119 Patiño Douce, A.E., 1999. What do experiments tell us about the relative contributions of
1120 crust and mantle to the origin of granitic magmas? Geological Society, London,
1121 Special Publications 168, 55–75. <https://doi.org/10.1144/GSL.SP.1999.168.01.05>

1122 Pearce, J.A., 2008. Geochemical fingerprinting of oceanic basalts with applications to
1123 ophiolite classification and the search for Archean oceanic crust. *Lithos* 100, 14–48.
1124 <https://doi.org/10.1016/j.lithos.2007.06.016>

1125 Pearce, J.A., Harris, N.B.W., Tindle, A.G., 1984. Trace Element Discrimination Diagrams for
1126 the Tectonic Interpretation of Granitic Rocks. *Journal of Petrology* 25, 956–983.
1127 <https://doi.org/10.1093/petrology/25.4.956>

1128 Peccerillo, A., Taylor, S.R., 1976. Geochemistry of eocene calc-alkaline volcanic rocks from
1129 the Kastamonu area, Northern Turkey. *Contr. Mineral. and Petrol.* 58, 63–81.
1130 <https://doi.org/10.1007/BF00384745>

1131 Polat, A., Hofmann, A.W., 2003. Alteration and geochemical patterns in the 3.7–3.8 Ga Isua
1132 greenstone belt, West Greenland. *Precambrian Research* 126, 197–218.
1133 [https://doi.org/10.1016/S0301-9268\(03\)00095-0](https://doi.org/10.1016/S0301-9268(03)00095-0)

- 1134 Pouclet, A., Tchameni, R., Mezger, K., Vidal, M., Nsifa, E., Shang, C., Penaye, J., 2007.
1135 Archaean crustal accretion at the northern border of the Congo Craton (South
1136 Cameroon). The charnockite-TTG link. *Bulletin de la Societe Geologique de France*
1137 178, 331–342. <https://doi.org/10.2113/gssgfbull.178.5.331>
- 1138 Qian, Q., Hermann, J., 2013. Partial melting of lower crust at 10–15 kbar: constraints on
1139 adakite and TTG formation. *Contrib Mineral Petrol* 165, 1195–1224.
1140 <https://doi.org/10.1007/s00410-013-0854-9>
- 1141 Rajesh, H.M., Santosh, M., 2012. Charnockites and charnockites. *Geoscience Frontiers*,
1142 Charnockites and Charnockites 3, 737–744. <https://doi.org/10.1016/j.gsf.2012.07.001>
- 1143 Rapp, R.P., Norman, M.D., Laporte, D., Yaxley, G.M., Martin, H., Foley, S.F., 2010.
1144 Continent Formation in the Archean and Chemical Evolution of the Cratonic
1145 Lithosphere: Melt–Rock Reaction Experiments at 3–4 GPa and Petrogenesis of
1146 Archean Mg-Diorites (Sanukitoids). *Journal of Petrology* 51, 1237–1266.
1147 <https://doi.org/10.1093/petrology/egq017>
- 1148 Rapp, R.P., Shimizu, N., Norman, M.D., Applegate, G.S., 1999. Reaction between slab-
1149 derived melts and peridotite in the mantle wedge: experimental constraints at 3.8 GPa.
1150 *Chemical Geology* 160, 335–356. [https://doi.org/10.1016/S0009-2541\(99\)00106-0](https://doi.org/10.1016/S0009-2541(99)00106-0)
- 1151 Rapp, R.P., Watson, E.B., 1995. Dehydration Melting of Metabasalt at 8–32 kbar:
1152 Implications for Continental Growth and Crust–Mantle Recycling. *Journal of*
1153 *Petrology* 36, 891–931. <https://doi.org/10.1093/petrology/36.4.891>
- 1154 Rubatto, D., 2017. Zircon: The Metamorphic Mineral. *Reviews in Mineralogy and*
1155 *Geochemistry* 83, 261–295. <https://doi.org/10.2138/rmg.2017.83.9>
- 1156 Rutter, M.J., Wyllie, P.J., 1988. Melting of vapour-absent tonalite at 10 kbar to simulate
1157 dehydration–melting in the deep crust. *Nature* 331, 159–160.
1158 <https://doi.org/10.1038/331159a0>

1159 Schiano, P., Monzier, M., Eissen, J.-P., Martin, H., Koga, K.T., 2010. Simple mixing as the
1160 major control of the evolution of volcanic suites in the Ecuadorian Andes. *Contrib*
1161 *Mineral Petrol* 160, 297–312. <https://doi.org/10.1007/s00410-009-0478-2>

1162 Shang, C.K., Liégeois, J.P., Satir, M., Frisch, W., Nsifa, E.N., 2010. Late Archaean high-K
1163 granite geochronology of the northern metacratonic margin of the Archaean Congo
1164 craton, Southern Cameroon: Evidence for Pb-loss due to non-metamorphic causes.
1165 *Gondwana Research* 18, 337–355. <https://doi.org/10.1016/j.gr.2010.02.008>

1166 Shang, C.K., Satir, M., Nsifa, E.N., Liégeois, J.-P., Siebel, W., Taubald, H., 2007. Archaean
1167 high-K granitoids produced by remelting of earlier Tonalite–Trondhjemite–
1168 Granodiorite (TTG) in the Sangmelima region of the Ntem complex of the Congo
1169 craton, southern Cameroon. *Int J Earth Sci (Geol Rundsch)* 96, 817–841.
1170 <https://doi.org/10.1007/s00531-006-0141-3>

1171 Shang, C.K., Satir, M., Siebel, W., Nsifa, E.N., Taubald, H., Liégeois, J.P., Tchoua, F.M.,
1172 2004a. TTG magmatism in the Congo craton; a view from major and trace element
1173 geochemistry, Rb–Sr and Sm–Nd systematics: case of the Sangmelima region, Ntem
1174 complex, southern Cameroon. *Journal of African Earth Sciences* 40, 61–79.
1175 <https://doi.org/10.1016/j.jafrearsci.2004.07.005>

1176 Shang, Siebel, W., Satir, M., Chen, F., Mvondo, J.O., 2004b. Zircon Pb–Pb and U–Pb
1177 systematics of TTG rocks in the Congo Craton: Constraints on crust formation,
1178 magmatism, and Pan-African lead loss. *Bulletin of Geosciences* 79, 205–219.

1179 Smithies, R.H., 2000. The Archaean tonalite–trondhjemite–granodiorite (TTG) series is not an
1180 analogue of Cenozoic adakite. *Earth and Planetary Science Letters* 182, 115–125.
1181 [https://doi.org/10.1016/S0012-821X\(00\)00236-3](https://doi.org/10.1016/S0012-821X(00)00236-3)

1182 Smithies, R.H., Champion, D.C., 2000. The Archaean high-Mg diorite suite: Links to
1183 Tonalite–Trondhjemite–Granodiorite magmatism and implications for early Archaean

1184 crustal growth. *Journal of Petrology* 41, 1653–1671.
1185 <https://doi.org/10.1093/petrology/41.12.1653>

1186 Smithies, R.H., Ivanic, T.J., Lowrey, J.R., Morris, P.A., Barnes, S.J., Wyche, S., Lu, Y.-J.,
1187 2018. Two distinct origins for Archean greenstone belts. *Earth and Planetary Science*
1188 *Letters* 487, 106–116. <https://doi.org/10.1016/j.epsl.2018.01.034>

1189 Smithies, R.H., Lu, Y., Johnson, T.E., Kirkland, C.L., Cassidy, K.F., Champion, D.C., Mole,
1190 D.R., Zibra, I., Gessner, K., Sapkota, J., De Paoli, M.C., Poujol, M., 2019. No
1191 evidence for high-pressure melting of Earth’s crust in the Archean. *Nat Commun* 10,
1192 5559. <https://doi.org/10.1038/s41467-019-13547-x>

1193 Sotiriou, P., Polat, A., Windley, B., Kusky, T., 2023. Temporal variations in the incompatible
1194 trace element systematics of Archean TTGs: Implications for crustal growth and
1195 tectonic processes in the early Earth. *Earth-Science Reviews* 236, 104274.
1196 <https://doi.org/10.1016/j.earscirev.2022.104274>

1197 Sun, S. -s., McDonough, W.F., 1989. Chemical and isotopic systematics of oceanic basalts:
1198 implications for mantle composition and processes. Geological Society, London,
1199 *Special Publications* 42, 313–345. <https://doi.org/10.1144/GSL.SP.1989.042.01.19>

1200 Sylvester, P.J., 1994. Chapter 7 Archean Granite Plutons, in: *Developments in Precambrian*
1201 *Geology*. Elsevier, pp. 261–314. [https://doi.org/10.1016/S0166-2635\(08\)70225-1](https://doi.org/10.1016/S0166-2635(08)70225-1)

1202 Takam, T., Arima, M., Kokonyangi, J., Dunkley, D.J., Nsifa, E.N., 2009. Paleoarchean
1203 charnockite in the Ntem Complex, Congo Craton, Cameroon: insights from SHRIMP
1204 zircon U-Pb ages. *Journal of Mineralogical and Petrological Sciences* 104, 1–11.
1205 <https://doi.org/10.2465/jmps.080624>

1206 Tchameni, R., Lerouge, C., Penaye, J., Cocherie, A., Milesi, J.P., Toteu, S.F., Nsifa, N.E.,
1207 2010. Mineralogical constraint for metamorphic conditions in a shear zone affecting
1208 the Archean Ngoulemakong tonalite, Congo craton (Southern Cameroon) and

1209 retentivity of U–Pb SHRIMP zircon dates. *Journal of African Earth Sciences* 58, 67–
1210 80. <https://doi.org/10.1016/j.jafrearsci.2010.01.009>

1211 Tchameni, R., Mezger, K., Nsifa, N.E., Pouclet, A., 2001. Crustal origin of Early Proterozoic
1212 syenites in the Congo Craton (Ntem Complex), South Cameroon. *Lithos* 57, 23–42.
1213 [https://doi.org/10.1016/S0024-4937\(00\)00072-4](https://doi.org/10.1016/S0024-4937(00)00072-4)

1214 Tchameni, R., Mezger, K., Nsifa, N.E., Pouclet, A., 2000. Neoproterozoic crustal evolution in
1215 the Congo Craton: evidence from K rich granitoids of the Ntem Complex, southern
1216 Cameroon. *Journal of African Earth Sciences* 30, 133–147.
1217 [https://doi.org/10.1016/S0899-5362\(00\)00012-9](https://doi.org/10.1016/S0899-5362(00)00012-9)

1218 Tchameni, R., Pouclet, A., Mezger, K., Nsifa, N.E., Vicat, J.P., 2004. Single zircon Pb–Pb and
1219 Sm–Nd whole rock ages for the Ebolowa greenstone belts: Evidence for pre-2.9 Ga
1220 terranes in the Ntem Complex (South Cameroon). *Journal of the Cameroon Academy*
1221 *of Sciences* 4, 235–246.

1222 Thiéblemont, D., Callec, Y., Fernandez-Alonso, M., Chène, F., 2018. A Geological and
1223 Isotopic Framework of Precambrian Terrains in Western Central Africa: An
1224 Introduction, in: Siegesmund, S., Basei, M.A.S., Oyhançabal, P., Oriolo, S. (Eds.),
1225 *Geology of Southwest Gondwana*. Springer International Publishing, Cham, pp. 107–
1226 132. https://doi.org/10.1007/978-3-319-68920-3_5

1227 Tomlinson, K.Y., Condie, K.C., 2001. Archean mantle plumes: evidence from greenstone belt
1228 geochemistry. *Geol. Soc. Am. Spec. Pap.* 352, 483–575.

1229 Toteu, S.F., de Wit, M., Penaye, J., Drost, K., Tait, J.A., Bouyo, M.H., Van Schmus, W.R.,
1230 Jelsma, H., Moloto-A-Kenguemba, G.R., da Silva Filho, A.F., Lerouge, C., Doucouré,
1231 M., 2022. Geochronology and correlations in the Central African Fold Belt along the
1232 northern edge of the Congo Craton: New insights from U–Pb dating of zircons from

1233 Cameroon, Central African Republic, and south-western Chad. *Gondwana Research*
1234 107, 296–324. <https://doi.org/10.1016/j.gr.2022.03.010>

1235 Toteu, S.F., Van Schmus, W.R., Penaye, J., Nyobé, J.B., 1994. U • Pb and Sm • N edvidence
1236 for Eburnian and Pan-African high-grade metamorphism in cratonic rocks of southern
1237 Cameroon. *Precambrian Research* 67, 321–347. [https://doi.org/10.1016/0301-](https://doi.org/10.1016/0301-9268(94)90014-0)
1238 9268(94)90014-0

1239 Trouw, R.A.J., Passchier, C.W., Wiersma, D.J., 2009. Atlas of Mylonites- and related
1240 microstructures. Springer Berlin Heidelberg, Berlin, Heidelberg.
1241 <https://doi.org/10.1007/978-3-642-03608-8>

1242 Vermeesch, P., 2018. IsoplotR: A free and open toolbox for geochronology. *Geoscience*
1243 *Frontiers* 9, 1479–1493. <https://doi.org/10.1016/j.gsf.2018.04.001>

1244 Wang, Q., Xu, J.-F., Jian, P., Bao, Z.-W., Zhao, Z.-H., Li, C.-F., Xiong, X.-L., Ma, J.-L.,
1245 2006. Petrogenesis of Adakitic Porphyries in an Extensional Tectonic Setting, Dexing,
1246 South China: Implications for the Genesis of Porphyry Copper Mineralization. *Journal*
1247 *of Petrology* 47, 119–144. <https://doi.org/10.1093/petrology/egi070>

1248 Wang, W., Cawood, P.A., Liu, S., Guo, R., Bai, X., Wang, K., 2017. Cyclic formation and
1249 stabilization of Archean lithosphere by accretionary orogenesis: Constraints from TTG
1250 and potassic granitoids, North China Craton: Cyclic Formation of Archean
1251 Lithosphere. *Tectonics* 36, 1724–1742. <https://doi.org/10.1002/2017TC004600>

1252 Watkins, J.M., Clemens, J.D., Treloar, P.J., 2007. Archean TTGs as sources of younger
1253 granitic magmas: melting of sodic metatonalites at 0.6–1.2 GPa. *Contrib Mineral*
1254 *Petrol* 154, 91–110. <https://doi.org/10.1007/s00410-007-0181-0>

1255 Watson, E.B., Harrison, T.M., 1983. Zircon saturation revisited: temperature and composition
1256 effects in a variety of crustal magma types. *Earth and Planetary Science Letters* 64,
1257 295–304. [https://doi.org/10.1016/0012-821X\(83\)90211-X](https://doi.org/10.1016/0012-821X(83)90211-X)

1258 Wiedenbeck, M., Allé, P., Corfu, F., Griffin, W.L., Meier, M., Oberli, F., Quadt, A.V.,
1259 Roddick, J.C., Spiegel, W., 1995. THREE NATURAL ZIRCON STANDARDS FOR
1260 U-TH-PB, LU-HF, TRACE ELEMENT AND REE ANALYSES. *Geostandards and*
1261 *Geoanalytical Research* 19, 1–23. <https://doi.org/10.1111/j.1751-908X.1995.tb00147.x>

1262 Windley, B.F., Kusky, T., Polat, A., 2021. Onset of plate tectonics by the Eoarchean.
1263 *Precambrian Research* 352, 105980. <https://doi.org/10.1016/j.precamres.2020.105980>

1264 Wu, F., Liu, X., Ji, W., Wang, J., Yang, L., 2017. Highly fractionated granites: Recognition
1265 and research. *Sci. China Earth Sci.* 60, 1201–1219. [https://doi.org/10.1007/s11430-](https://doi.org/10.1007/s11430-016-5139-1)
1266 [016-5139-1](https://doi.org/10.1007/s11430-016-5139-1)

1267 Wu, Y., Zheng, Y., 2004. Genesis of zircon and its constraints on interpretation of U-Pb age.
1268 *Chin.Sci.Bull.* 49, 1554–1569. <https://doi.org/10.1007/BF03184122>

1269 Zhang, X., Yuan, L., Xue, F., Zhai, M., 2014. Neoproterozoic metagabbro and charnockite in the
1270 Yinshan block, western North China Craton: Petrogenesis and tectonic implications.
1271 *Precambrian Research, Precambrian Geological events and Mineralization of the*
1272 *North China Craton* 255, 563–582. <https://doi.org/10.1016/j.precamres.2013.11.003>

1273 Zhao, K., Xu, X., Klemd, R., He, Z., Zhang, X., 2023. A review of the genetic mechanisms
1274 generating igneous charnockite: CO₂ flushing and crystal-melt segregation in mushy
1275 reservoirs. *Earth-Science Reviews* 237, 104295.
1276 <https://doi.org/10.1016/j.earscirev.2022.104295>

1277 Zheng, D., Wu, S., Ma, C., Xiang, L., Hou, L., Chen, A., Hou, M., 2022. Zircon classification
1278 from cathodoluminescence images using deep learning. *Geoscience Frontiers* 13,
1279 101436. <https://doi.org/10.1016/j.gsf.2022.101436>

1280 Zheng, Y.-F., 2019. Subduction zone geochemistry. *Geoscience Frontiers* 10, 1223–1254.
1281 <https://doi.org/10.1016/j.gsf.2019.02.003>

1282 Zhou, Y., Zhao, T., Sun, Q., Zhai, M., 2018. Geochronological and geochemical constraints
1283 on the petrogenesis of the 2.6–2.5 Ga amphibolites, low- and high-Al TTGs in the
1284 Wangwushan area, southern North China Craton: Implications for the Neoproterozoic
1285 crustal evolution. *Precambrian Research* 307, 93–114.
1286 <https://doi.org/10.1016/j.precamres.2018.01.013>

1287 Zhu, D., Mo, X., Wang, L., Zhao, Z., Niu, Y., Zhou, C., Yang, Y., 2009. Petrogenesis of
1288 highly fractionated I-type granites in the Zayu area of eastern Gangdese, Tibet:
1289 Constraints from zircon U-Pb geochronology, geochemistry and Sr-Nd-Hf isotopes.
1290 *Sci. China Ser. D-Earth Sci.* 52, 1223–1239. <https://doi.org/10.1007/s11430-009->
1291 [0132-x](https://doi.org/10.1007/s11430-009-0132-x)

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1313 **Figure captions**

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1315 **Fig. 1. a)** Africa map showing the distribution of Archean-Paleoproterozoic cratons and Sahara
1316 Metacraon and the Arabian-Nubian shield. The inset shows the outline of Ntem Complex and
1317 the location of the Congo Craton. **b)** Simplified geological map of the southwestern Cameroon
1318 (modified after Maurizot et al., 1986). The study area is shown in the rectangle.

1319 **Fig. 2.** Representative field photographs of granitoids from the NGB.

1320 **Fig. 3.** Photomicrographs of representative samples: (a, b) Charnockites samples (JA8 and
1321 JA12) showing typical mineral assemblages of hypersthene + clinopyroxene + plagioclase +
1322 hornblende + biotite ± quartz ± alkali feldspar; (c, d) TTG gneisses samples (JA11, MNN)
1323 showing the orientation of deformed porphyroclasts of plagioclase, biotite, hornblende and
1324 quartz with zoned plagioclase altered to sericite. Perthite and microperthite structures are well-
1325 developed in feldspar; (e, f) Granitic gneisses with the medium- grained granoblastic texture
1326 with the orientation of deformed porphyroclasts of quartz, plagioclase and alkali feldspar; (g,
1327 h) Recrystallized quartz and biotite, defining the deformation fabric in the mylonite in zone,
1328 plagioclase altered to sericite, and pyrite are common in the NGB high-strain zone
1329 monzogranites (sample U2, U2.1). Mineral abbreviations: Opx-Orthopyroxene; Cpx-
1330 Clinopyroxene; Hlb-Hornblende; Qtz-Quartz; Pl-Plagioclase; Kf-Alkali feldspar; Mc-
1331 Microcline; Bt-Biotite; Ms- Muscovite; Chl-Chlorite; Per-Perthite; Zr-Zircon; Ap-Apatite.

1332 **Fig.4** (a) Multicationic classification diagram for Nyabessane granitoids (after Debon and Fort,
1333 1983). (b) Normative Albite (Ab)–Anorthite (An)–Orthoclase (Or) (after Barker, 1979). (c)
1334 Ternary classification diagram for late Archaean granitoids: $2 \cdot A/CNK$ (molar $Al_2O_3/[CaO +$
1335 $Na_2O + K_2O]$ ratio)- Na_2O/K_2O ratio-2FMSB) (after Laurent et al., 2014). (d) $FeOt/(FeOt +$
1336 $MgO)$ vs. SiO_2 (wt. %), (e) $Na_2O + K_2O - CaO$ vs. SiO_2 (wt. %) and (f) A/NK vs. A/CNK .

1337 **Fig. 5.** Harker diagrams showing the major compositional variations with silica for different
1338 granitoids of Nyabessane terrane. (c) MgO versus SiO₂ diagram (experimental partial melts
1339 from metabasaltic rocks; low-silica adakite; high-silica adakite; Martin et al., 2005).

1340 **Fig. 6.** Chondrite-normalized rare earth element (REE) and primitive mantle-normalized multi-
1341 elemental variation diagram for the charnockites (a, b), TTG gneisses (c, d), granitic gneisses
1342 (e, f) and monzogranitic gneisses (g, h). Normalized Primitive mantle values are from Sun and
1343 McDonough, (1989) and Chondrite values are from Anders and Grevesse (1989). The average
1344 Archean TTG data are from Halla et al. (2017).

1345 **Fig. 7.** Summary of zircon LA-SF-ICP-MS U-Pb and representative cathodoluminescence
1346 images of zircons, with the position of laser spots. U-Pb isotopic data plotted in Wetherill
1347 Concordia diagrams, with insets showing the ²⁰⁷Pb/²⁰⁶Pb calculated date of the corresponding
1348 spots. We report upper intercept dates for information, although some of them unlikely
1349 represent crystallization ages because of multiple Pb loss events and severe discordance. Error
1350 ellipses and bars all represent 2σ uncertainties. Dark grey filled ellipses were not used for
1351 calculation of intercept ages.

1352 **Fig. 8.** (a) Al₂O₃/(FeOt + MgO)–3*CaO–5*(K₂O/Na₂O) ternary diagram (after Laurent et al.,
1353 2014); (b) Mg#–SiO₂ diagram (after Rapp et al., 1999; Smithies and Champion, 2000; Deng et
1354 al., 2016); (c) Sr/Y vs Y diagram (after Drummond and Defant, 1990); (d) (La/Yb)_N vs Yb_N
1355 diagram (after Martin, 1987); (e) La/Hf vs La diagram (after Schiano et al., 2010). (f) Mg#
1356 versus La/Sm (after Chen et al., 2019). Vector arrows show the effects of increasing degrees of
1357 partial melting and fractionation.

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1359 **Fig. 9.** (a) Cr vs Mg# diagram showing the lower Cr contents and moderated Mg# of the NGB
1360 TTG gneisses similar to the lower crust–derived Eoarchean TTGs and experimental TTG melts
1361 (Qian and Hermann, 2013). (b, c) Ce/Sr – Y(ppm) and Sr/Y – Y(ppm) plots showing the

1362 compositions of all studies samples compared to mineral and experimental modelled melts
1363 (Laurent et al., 2020). (d) Sr/Y – La/Yb plot of NGB granitoids TTGs are compared to different
1364 proportions of crystals and experimental melt (Kendrick et al., 2022). Amphibole (Am) and
1365 plagioclase (Pl). The fields for low-, medium- and high-pressure TTGs (Moyen 2011). (e, f)
1366 Geochemical classification diagrams for the adakites (after Wang et al., 2006; Li et al., 2023b).
1367 (g, h) La_N vs. FeOt+MgO and Nb+Zr+Y vs. FeOt+MgO plots (Laurent et al., 2014). BC-bulk
1368 crust, UC-upper crust.

1369 **Fig. 10.** Tectonic setting discrimination diagrams for NGB Mesoarchean granitoids. (a)
1370 Rb(ppm) vs Nb+Y (ppm) tectonic setting discrimination diagrams for granites (Pearce et al.,
1371 1984) . (b) Nb (ppm) versus Y (ppm) tectonic setting discrimination diagram for TTGs
1372 (modified after Hildebrand and Whalen, 2014). (c, d) La/Yb versus Sr/Y and Gd/Yb versus
1373 Sr/Y plot of slab failure versus arc pluton discrimination diagrams for Mesoarchean granitoids
1374 from Nyabessane area (modified after Hildebrand and Whalen, 2017). (e) Nb/Nb* versus
1375 Pb/Pb* anomaly ratio plot for NGB Mesoarchean granitoids (modified after Sotiriou et al.,
1376 2023). Nb/Nb* ($Nb/Nb^* = Nb_N / (Th_N \times La_N)^{0.5}$; N-MORB normalized value Sun and
1377 McDonough, 1989) and Pb/ Pb* ($Pb/Pb^* = Pb_N / (Ce_N \times Pr_N)^{0.5}$) anomaly ratios of <1 and > 1 are
1378 indicative of a subduction origin. (f) The Th/Yb vs Nb/Yb diagram of Pearce (2008) Pearce
1379 (2008) for the NGB granitoids showing main fields as well as composition vectors expected
1380 during subduction enrichment of a mantle source, crustal assimilation, and partial melting.
1381 Oceanic and continental arc domains were adapted according to Smithies et al., (2018) and
1382 Brown et al. (2020). E-MORB, enhanced mid-ocean ridge basalt; LCC, lower continental crust;
1383 MORB, mid-ocean ridge basalt; N-MORB, normal mid-ocean ridge basalt; OIB, ocean island
1384 basalt (Sun and McDonough, 1989).

1385 **Tables.**

1386 **Table 1.** Major (wt%) and trace (ppm) element contents of Nyabessane granitoids

Table1. Major (wt%) and trace (ppm) element contents of Nyabessane granitoids

Rock type	Granitic gneiss			Charnokite		TTG gneiss									Monzogranite				
Lat/Long	<i>N02°14'28.1" /E010°13'26.5"</i>	<i>N02°22'17.8" /E010°20'48.4"</i>	<i>N02°22'46.6" /E010°21'47.8"</i>	<i>N02°26'06.4" /E010°29'38.4"</i>	<i>N02°14'28.1" /E010°13'26.5"</i>	<i>N02°22'21.1" /E010°20'53.4"</i>	<i>N02°22'46.6" /E010°21'47.1"</i>	<i>N02°24'14.0" /E010°22'52.0"</i>	<i>N02°24'16.8" /E010°22'54.1"</i>	<i>N02°22'25.4" /E010°20'52.4"</i>	<i>N02°22'47.1" /E010°21'49.4"</i>	<i>N02°24'15.0" /E010°22'52.6"</i>	<i>N02°22'14.4" /E010°20'49.5"</i>	<i>N02°24.263' /E010°22.854'</i>	<i>N02°22'25.9" /E010°20'53.4"</i>	<i>N02°22'23.4" /E010°20'52.6"</i>	<i>N02°22'16.1" /E010°20'49.2"</i>	<i>N02°22'26.1" /E010°20'53.0"</i>	
Sample No.	JA1	JA5	JA18	JA8	JA12	JA4	JA17	MN	MNN	U1	JA22	JA9	JA11	MNN1	U2	U2.1	U3	U5	
SiO ₂	74.28	76.89	76.44	55.90	58.04	73.30	70.78	60.01	64.64	68.75	75.05	65.58	63.57	72.56	77.48	73.50	74.08	75.23	
TiO ₂	0.17	0.08	0.08	0.44	0.52	0.27	0.44	0.66	0.42	0.33	0.23	0.56	0.44	0.25	0.19	0.11	0.17	0.06	
Al ₂ O ₃	13.03	13.15	13.15	18.00	16.08	14.27	14.45	13.24	16.13	15.98	13.68	14.95	15.49	14.43	12.82	13.56	12.67	12.62	
Fe ₂ O ₃	1.15	1.06	1.08	7.26	8.13	2.59	4.18	8.45	4.99	3.31	6.02	5.21	1.80	2.10	0.61	1.12	0.96	1.58	
MnO	0.01	0.00	0.04	0.10	0.12	0.03	0.04	0.10	0.07	0.04	0.01	0.07	0.07	0.04	0.00	0.01	0.02	0.07	
MgO	0.50	0.33	0.32	4.43	4.63	0.87	1.38	4.52	2.65	1.22	0.24	1.84	2.64	0.72	0.01	0.39	0.01	0.01	
CaO	0.78	0.04	0.11	8.19	7.15	1.53	3.55	5.48	4.85	2.45	1.38	4.01	4.76	2.02	0.93	0.87	1.51	2.59	
Na ₂ O	2.50	4.08	3.98	4.59	3.78	4.18	3.94	3.19	4.72	5.30	4.37	4.44	4.53	3.74	4.19	3.65	3.86	3.11	
K ₂ O	6.04	4.81	4.88	1.39	1.62	3.35	1.43	2.48	2.63	2.42	3.38	1.29	2.58	3.86	4.42	4.91	4.14	4.61	
P ₂ O ₅	0.02	0.00	0.00	0.10	0.23	0.08	0.07	0.37	0.23	0.11	0.06	0.32	0.22	0.00	0.04	0.03	0.03	0.01	
LOI	0.77	0.57	0.61	1.35	0.39	1.07	0.39	0.85	0.35	1.57	0.47	1.31	0.46	0.52	0.31	0.72	0.42	0.47	
Total	99.3	101.0	100.7	101.8	100.7	101.6	100.7	99.4	101.7	101.5	100.7	100.4	100.0	100.2	101.00	98.9	97.9	100.3	
K ₂ O/Na ₂ O	2.42	1.18	1.23	0.30	0.43	0.80	0.36	0.78	0.56	0.46	0.77	0.29	0.57	1.03	1.05	1.34	1.07	1.48	
Mg#	46.47	38.27	37.18	54.75	53.01	40.07	39.62	51.46	51.23	42.20	7.34	41.19	74.39	40.43	3.45	40.73	1.93	1.74	
A/NK	1.22	1.10	1.11	1.99	2.02	1.36	1.80	1.67	1.52	1.41	1.26	1.72	1.51	1.40	1.10	1.20	1.17	1.25	
A/CNK	1.08	1.10	1.09	0.75	0.77	1.07	1.00	0.74	0.83	1.01	1.02	0.93	0.82	1.03	0.96	1.05	0.93	0.85	
Sc	4.69	2.29	2.41	18.77	22.59	3.94	11.34	12.75	5.44	6.08	4.99	16.39	13.47	26.28	2.39	2.27	2.31	1.65	
V	28.65	9.31	11.57	134.11	126.71	35.46	79.14	106.28	30.86	50.23	13.81	102.43	110.23	195.76	12.52	12.92	14.28	16.03	
Cr	-	0.00	-	75.14	134.72	1.65	35.04	38.54	1.46	14.63	-	20.79	38.63	81.54	-	-	-	-	
Co	2.74	1.65	2.18	29.50	23.07	5.82	14.13	16.69	4.59	12.16	2.47	14.94	17.09	24.44	11.75	2.66	10.56	3.98	
Ni	2.28	-	0.36	93.33	34.85	9.03	25.36	19.00	4.19	16.64	0.36	21.80	19.06	37.07	1.18	-	0.53	1.24	
Cu	9.04	11.55	0.00	67.54	17.00	8.34	55.71	127.46	63.53	17.63	65.64	12.66	38.21	3.90	9.14	4.33	8.56	1.01	
Zn	7.92	-	0.20	74.24	69.56	25.06	50.76	57.31	27.05	34.34	0.17	63.87	62.32	66.17	-	0.40	-	-	
Ga	13.54	13.79	15.50	21.62	16.81	17.68	18.62	23.37	21.63	23.08	31.95	32.24	30.43	32.40	11.24	15.93	11.37	16.57	
Rb	115.49	80.88	83.81	27.37	47.49	66.06	45.89	61.90	102.46	53.47	104.30	30.98	51.16	68.85	57.78	81.36	53.76	68.72	
Sr	349.21	242.25	336.91	611.63	549.07	387.58	384.07	1109.90	414.20	490.18	291.88	557.84	1005.31	785.58	191.04	315.40	267.47	514.77	
Y	2.22	1.67	1.73	12.30	16.19	5.74	5.49	9.82	11.61	5.39	22.95	33.84	11.18	25.22	1.27	1.76	1.11	1.85	
Zr	178.55	91.56	98.46	49.96	117.20	83.09	428.05	163.65	114.49	180.98	361.95	205.65	243.16	255.25	129.07	108.65	128.44	56.99	
Nb	2.36	0.29	0.34	4.32	4.67	3.23	3.65	3.04	3.91	2.57	18.65	8.65	3.62	9.88	0.66	0.44	0.37	0.02	
Ba	1976.24	1009.81	1153.21	509.11	988.43	1548.45	463.61	1647.15	1527.86	1107.34	1451.07	836.43	1603.35	1182.58	1739.24	1594.02	1709.17	1238.14	

Ge	2.10	2.79	2.39	4.51	1.24	2.33	2.29	4.61	4.38	4.34	7.79	8.78	8.32	9.62	2.20	2.74	2.12	3.03
Hf	5.09	2.60	3.05	1.47	2.86	2.19	9.88	3.78	3.04	4.99	8.84	4.76	5.65	6.14	3.39	3.22	3.37	1.91
Pb	16.66	9.52	11.77	5.49	13.18	4.28	6.47	11.24	12.98	5.79	11.48	4.79	10.77	6.62	6.29	9.74	5.06	6.20
Th	7.46	15.03	15.58	1.16	1.91	1.44	0.35	1.23	15.72	16.29	41.31	12.32	35.45	13.75	11.77	15.33	8.26	10.82
U	0.39	1.01	1.03	0.00	0.48	0.22	0.47	0.13	0.58	0.82	1.86	0.20	0.39	0.59	0.21	0.76	0.23	0.42
La	16.25	23.73	23.82	25.20	18.79	18.58	14.47	38.64	51.61	50.38	114.20	74.44	105.13	74.23	30.33	27.91	28.34	35.49
Ce	30.23	42.33	44.24	53.85	38.60	32.65	24.97	72.06	90.32	87.03	195.36	147.01	173.52	144.50	52.64	48.12	48.01	56.61
Nd	11.23	14.19	14.43	24.70	18.34	11.99	10.41	32.51	32.02	29.83	59.21	63.60	58.50	66.26	15.81	16.28	14.77	17.11
Sm	1.80	1.95	2.04	3.95	3.66	1.85	1.56	5.17	4.68	3.96	7.41	12.53	7.36	10.89	1.53	2.02	1.32	1.62
Eu	0.89	0.41	0.48	1.05	1.05	0.64	0.65	1.47	0.94	0.77	1.28	1.20	1.59	2.16	0.53	0.54	0.50	0.68
Pr	3.11	4.23	4.20	6.22	4.75	3.45	2.77	8.27	9.30	8.76	18.65	16.57	16.95	16.72	4.88	4.67	4.60	5.27
Gd	1.17	1.18	1.16	2.95	3.24	1.44	1.30	3.43	3.07	2.41	4.92	10.34	4.54	7.98	0.72	1.07	0.62	0.84
Dy	0.57	0.44	0.41	2.33	2.75	1.01	0.99	1.90	2.30	1.17	3.91	7.71	2.23	5.11	0.27	0.44	0.25	0.39
Tb	0.12	0.09	0.11	0.37	-	0.20	0.17	0.35	0.38	0.24	0.63	1.39	0.42	0.97	0.05	0.10	0.05	0.08
Ho	0.08	0.06	0.06	0.44	0.54	0.20	0.17	0.34	0.42	0.20	0.74	1.34	0.38	0.89	0.04	0.06	0.05	0.06
Er	0.21	0.13	0.18	1.18	1.46	0.52	0.55	0.88	1.11	0.46	2.24	3.25	0.98	2.33	0.11	0.15	0.11	0.16
Tm	0.03	0.02	0.02	0.17	-	0.06	0.08	0.11	0.16	0.06	0.32	0.38	0.13	0.30	0.01	0.02	0.01	0.02
Yb	0.19	0.13	0.13	1.00	1.40	0.36	0.53	0.78	1.01	0.39	2.19	2.03	0.90	1.93	0.12	0.15	0.12	0.15
Lu	0.03	0.02	0.02	0.13	0.22	0.05	0.10	0.10	0.12	0.06	0.29	0.24	0.11	0.23	0.01	0.02	0.02	0.02
Sr/Y	157.13	145.02	194.29	49.72	33.92	67.55	16.48	89.94	69.90	12.72	31.14	113.1	35.68	91.03	150.2	179.5	241.01	278.26
La/Yb	85.69	189.63	180.02	25.24	13.45	51.18	36.74	117	27.50	52.15	38.47	49.47	50.90	129	254.01	185.40	244.37	235.23
Th/Yb	39.35	120.08	117.75	1.16	1.37	3.98	6.08	39.44	0.67	18.87	7.13	1.57	15.50	41.71	98.56	101.82	71.19	71.66
Th/Nb	3.16	52.15	45.81	0.27	0.41	0.45	1.42	9.79	0.10	2.21	1.39	0.40	4.02	6.34	17.96	34.74	22.39	487.31
Gd/Yb	6.18	9.40	8.78	2.96	2.32	3.96	5.10	5.05	2.47	2.25	4.13	4.39	3.02	6.16	6.05	7.08	5.32	5.58
Ce/Th	1.86	1.78	1.86	2.14	2.05	1.76	1.97	1.65	1.73	1.71	1.95	1.86	1.75	1.73	1.74	1.72	1.69	1.60
Eu/Eu*	1.87	0.82	0.95	0.94	0.93	1.19	1.39	1.06	0.75	0.76	0.64	0.32	0.84	0.70	1.54	1.12	1.68	1.76
La _N /Yb _N	59.33	131.29	124.64	17.47	9.31	35.44	19.04	34.25	35.24	89.32	36.11	25.44	81.00	26.64	175.87	128.36	169.19	162.71
La _N /Sm _N	5.65	7.61	7.32	4.00	3.22	6.28	5.82	4.68	6.91	7.98	9.66	3.72	8.95	4.27	12.46	8.66	13.42	13.75
Zr _N /Nb _N	4.82	20.24	18.43	0.74	1.60	1.64	1.51	4.27	7.46	1.24	1.64	3.43	1.86	4.49	12.54	15.67	22.18	164.13
Th _N /Nb _N	26.53	437.56	384.22	2.25	3.42	3.75	11.95	82.11	0.81	18.58	11.68	3.38	33.70	53.20	150.68	291.37	187.85	4106.84
La _N /Nb _N	7.26	86.63	73.38	6.11	4.12	5.96	8.90	30.12	4.10	0.65	7.79	13.15	13.67	20.27	47.88	66.24	79.30	1677.42

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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