



The Mount Manengouba, a complex volcano of the Cameroon Line: Volcanic history, petrological and geochemical features

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1 **The Mount Manengouba, a complex volcano of the Cameroon Line:**
2 **Volcanic history, petrological and geochemical features**

3

4

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25 **Keywords:** Cameroon Volcanic Line, Manengouba volcano, alkaline magmatism, Quaternary
26 volcanism, K/Ar and $^{40}\text{Ar}/^{39}\text{Ar}$ age dating, Caldera collapse, Olivine and pyroxene
27 thermobarometry, Sr- Nd- Pb-isotopes, Mantle source components

28 **ABSTRACT**

30

31 The volcanic story of Mount Manengouba is related to four chronological stages: 1) forming
32 of the early Manengouba shield volcano between 1.55 and 0.94 Ma, 2) building of the Eboga
33 strato-cone between 0.94 and 0.89 Ma, 3) caldera collapse and silicic extrusions of the

34 Elengoum Complex between 0.89 and 0.70 Ma, and 4) intra-caldera and flank activity
 35 between 0.45 and 0.11 Ma. The volume of the volcano is calculated at $320 \text{ km}^3 \pm 5\%$. The
 36 volcanic rocks are attributed to two magmatic outputs. The first and main magma generation
 37 produced the shield volcano, the strato-cone, and the syn- to post-caldera extrusions,
 38 displaying a complete series from basanites to trachytes (magmatic Group 1). The second
 39 magma generation is limited to the late and flank activity evolving from basanites to trachy-
 40 phonolite (magmatic Group 2). Both magmatic groups belong to the under-saturated alkaline
 41 sodic series. Petrological calculations locate the magmatic reservoir between 37 and 39 km in
 42 the upper mantle for the Group 1 lavas, and between 42 and 44 km for the Group 2 lavas.
 43 Trachytes were generated in a secondary crustal reservoir. Magmatic series evolve with
 44 medium to low pressure fractional crystallization of olivine, pyroxene, oxides, feldspar, and
 45 apatite. Significant crustal assimilation is evidenced in trachytes. The magma of Group 1 was
 46 generated with 3 to 6% of partial melting of a moderately enriched source containing 3 to 7%
 47 of garnet. Melting took place in the spinel to garnet transition zone located at 70 to 90 km and
 48 around 25 kb. The magma of Group 2 resulted from a slightly higher partial melting from a
 49 less garnet-rich source that indicates uprising of the melting column in the upper part of
 50 transition zone. Sr, Nd, and Pb isotope data of the Manengouba rocks and neighbouring lavas
 51 are analyzed and compared with those of the mafic lavas of the CVL. Three source
 52 components are distinguished: a depleted component originated from the asthenospheric
 53 swell, a radiogenic component linked to the contaminated lithosphere of the Neoproterozoic
 54 mobile belt, and an enriched component or the lithosphere possibly related to pre-rifting
 55 magmatic processes.

56 **1. Introduction**

57 Mount Manengouba is one of the great continental volcanoes of the Cameroon Line,
 58 consisting of the Mts Cameroon, Bambouto, Bamenda, and Oku (**Fig. 1**). The Cameroon Line
 59 is a transtensional passive rift, showing an alternation of volcanic horsts and grabens (Moreau
 60 et al., 1987; Meyers et al., 1988; Déruelle et al., 2007). Tectonic extension caused lithospheric
 61 thinning, asthenospheric upwelling and the formation of a magmatic hot line, trending N30°E.
 62 An important volcanic activity took place along the Line, from the Eocene to recent times
 63 (Déruelle et al., 1991). Present activity is restricted to Mount Cameroon (Wandji et al., 2009)
 64 and Bioko Island, but numerous Quaternary eruptions have occurred in the volcanic areas of
 65 Tombel, Manengouba, Bambouto, Noun, and Oku (Déruelle et al., 1991, 2000; Kagou
 66

68 Dongmo et al., 2001; Nkouathio et al., 2002; Suh et al., 2003; Itiga et al., 2004; Wotchoko et
69 al., 2005; Kagou Dongmo et al., 2010).

70 The Mount Manengouba is located 120 km north-east of Mount Cameroon, between
71 09°42' to 10°10' E, and 4°49' to 5°15' N (**Fig. 2**). It mainly consists of a shield volcano
72 overlain by a stratovolcano that culminates at 2411 m and covers 500 km². It is set up on a
73 volcano-tectonic height trending N30°E above the uplifted granite basement and crosscut by
74 N 0°, N 30° to 50°E and N 140°E faults. Along this height, there is an alternation of horst and
75 graben structures. The Manengouba volcano emplaced at the northern end of the Tombel
76 graben in the sedimentary Manjo and Mbo plains limited by two N 30°E trending normal
77 faults: the Tombel Fault to the west and the Nlonako Fault to the east (Fig. 1B).

78 Since Gouhier et al. (1974), Tchoua (1974), Dunlop (1983), and Fitton and Dunlop (1985),
79 a volcanological pattern has been assumed for the Manengouba building. The Mount
80 Manengouba was built between 1.55 Ma and 0 Ma during three stages (Kagou Dongmo,
81 1998, 2006; Kagou Dongmo et al., 2001). The first stage, from 1.55 to 0.7 Ma, corresponds to
82 the formation of a basaltic shield volcano evolving to a stratovolcano named Elengoum,
83 which was capped by trachyte domes and flows. The second stage, between 0.7 and 0.56 Ma,
84 points to the collapse of the Elengoum summit that created a large caldera which opened to
85 the west. The third stage, from 0.56 Ma to recent time, includes the building-up of a new
86 stratovolcano named Eboga inside the caldera. Then the collapse of the Eboga summit formed
87 the Eboga caldera enclosed in the former caldera of Elengoum. Finally, since 0.48 Ma,
88 numerous flank eruptions, mainly basaltic, supplied lava flows on the Manengouba slopes.
89 The volcanic rocks belong to the alkaline sodic series, evolving from basanite to trachyte.

90 Conducting new mapping, we established geological contradictions with the commonly
91 accepted history of the volcanic activity. New sample analyses were done and new ages were
92 obtained by K/Ar and ⁴⁰Ar/³⁹Ar methods. These data led to a complete revision of the
93 conventional Manengouba history. Petrological and magmatic features are documented from
94 mineral and chemical analyses. Trace elements and Sr, Nd, and Pb isotopes are used to
95 constrain the magma source composition.

96

97 **2. The Manengouba volcano, reappraisal of the volcanic history**

98

99 The geological pattern of the volcano has been reviewed. A new map is drawn, using
100 recent aerial photographs, suitable satellite imagery and field work surveys. The reduced map
101 is given on Figure 2 and detailed on **Figures 3 and 4**.

102

103 *2.1. The pre-Manengouba formations*

104 The lavas of the basal shield volcano overflowed the Cretaceous and Quaternary lacustrine
 105 and fluvial sediments of the northern end of the Tombel Graben. The Precambrian granite
 106 basement is exposed on the SW, S, E, and NE sides. The south-eastern border was intruded by
 107 a small syenite intrusion and associated rocks, the Mount Nlonako (Fig. 2), in middle Eocene
 108 between 43-46 Ma according to K-Ar age geochronology by Tchoua (1974) and Cantagrel et
 109 al. (1978). A similar intrusion, the Mount Koupé took place to the south-west of the
 110 Manengouba area (Fig. 1) and is dated at 53 Ma (Rb/Sr isotopic age in Lamilen, 1989). These
 111 intrusions belong to the Cretaceous to Eocene alkaline complex alignment from the Gulf of
 112 Guinea to the Lake Chad and betray the initial magmatic activity of the Cameroon tectonic
 113 line (Moreau et al., 1987; Déruelle et al., 1991). The north-western area exhibits thick
 114 ignimbritic flows and abundant extrusive domes of phonolite and trachyte that built Mounts
 115 Bakossi and Ekomane on both sides of the Bangem breach. Similar lavas are disseminated as
 116 small outcrops to the north and south of the Manengouba area. Previous dating of a trachyte
 117 dome of Ekomane yields a Middle Miocene age (Dunlop, 1983). These volcanic products can
 118 be related to the Miocene acidic activity of Mount Bambouto, north of Mount Manengouba
 119 (Youmen et al., 2005; Kagou Dongmo et al., 2010). A noticeable sight of this work is the
 120 discovery of old mafic lavas preserved along the western base of the Nlonako hill by means of
 121 tectonic uplift. The first flows of Manengouba came into contact with these pre-Manengouba
 122 lavas while the youngest flows from flank cones covered some parts of them. These later
 123 young lavas include 5 to 10 cm sized angular xenoliths of the old mafic lavas, indicating that
 124 these old lavas are set beneath Mount Manengouba. A new age dating is provided.

125

126 *2.2. The Manengouba formations*

127 Taking into account the piling up of different volcanic formations of Mount Manengouba,
 128 we distinguished four main chronological units and formational stages from the early shield
 129 volcano to the late flank lavas.

130

131 1) The early Manengouba shield volcano

132 The oldest lavas crop out all around the main building on the middle and low slopes. They
 133 consist of stacked lava flows of ankaramite, basalt and hawaiite. Spectacular stacking of these
 134 lavas can be seen in the canyon of the Nkam river, at the Ekom Nkam water fall, north-east of
 135 the Manengouba field (Fig. 2). These lavas belong to a large shield volcano that was the

136 primary Manengouba building. They are capped by more evolved lavas of the upper volcanic
137 edifice and overlain by numerous parasitic cones and their lava flows.

138

139 2) The Eboga stratovolcano

140 The upper mountain is a stratovolcano named Eboga and made of alternating, more
141 evolved lavas flows and pyroclastic deposits. The lava composition is dominated by
142 mugearites though hawaiites and benmoreites also occur. The northern and north-eastern
143 upper flanks are covered by benmoreite flows. The summit of the edifice collapsed in a
144 roughly circular caldera, averaging 4 km in diameter (Fig. 3). An arc-shaped scarp to the
145 north-eastern upper slope is attributed to this collapse event and not to a former caldera
146 because the scarp plan crosscut the Eboga flows that have outpoured from the initial crater.
147 The caldera was filled with basaltic flows contemporaneously with the late flank volcanic
148 activity until its north-western breach. Thus, the extent of the sinking event is unknown as
149 well as the height of the initial crater rim. The present day height of the caldera wall reaches
150 200 m.

151 The formation of the Eboga cone is the continuation of the activity of the early shield
152 volcano assuming a magmatic evolution from fluid mafic lavas to more viscous differentiated
153 lavas.

154

155 3) The Elengoum Extrusive Complex

156 The Eboga south-eastern upper slope is overlapped by thick trachyte pyroclastic flows and
157 benmoreite to trachyte domes which constitute the Elengoum Extrusive Complex (EEC).
158 Numerous bodies of similar composition extruded the summit part of the Eboga, and
159 particularly the caldera wall in using the circular faults of the caldera and the north-eastern
160 arc-shaped fault (Fig. 3). Consequently it is obvious that the formation of the EEC postdates
161 the formation of the Eboga cone. Definitely, the Elengoum cannot be attributed to a pre-
162 Eboga volcanic stage. One may assume that the Elengoum trachytic lava withdrawal of the
163 magma chamber was linked to the Eboga caldera collapse. The tectonic location of the EEC is
164 controlled by the major SW-NE trending fracture system (Fig. 2).

165 A singular acidic dome, the Ekom rhyolite extrusion, seems to intrude the basalt flows of
166 the early Manengouba shield at the north-eastern lower slope. The meaning of this activity is
167 questionable.

168

169 4) Flank cones and flows

170 All around the main cone but also on the upper flanks and inside the caldera, ca. one
 171 hundred parasitic and monogenetic cones are set up along short fractures, mainly trending
 172 SW-NE and WSW-ENE. The cones resulted from common strombolian activities and
 173 supplied lava flows of one to ten kilometres in length. In addition, three maar volcanoes are
 174 pointed out: one on the eastern upper flank and two inside the caldera (DS, LF and LH in
 175 Figure 3). The intra-caldera maars were emplaced along a SW-NE fracture, formerly used by
 176 the C2 strombolian cone, and two trachytic extrusions of the caldera wall. Indeed, they
 177 postdate the two strombolian cones C1 and C2, because their volcaniclastic debris covered the
 178 cones. In addition, a plug-dome named Mboriko extruded the caldera floor along a short
 179 SSW-NNE fracture. A significant amount of cones took place in the eastern upper slope,
 180 namely the supra-caldera strombolian volcanic complex (SCSV, Fig. 3) and the strombolian
 181 cone set above the caldera edge that is the summit of Mount Manengouba at 2,411 m. Most of
 182 the lavas are basanites and hawaiites, whilst mugearites are also common.

183

184 Assuming that Mount Manengouba rests above the granitic substratum that crops out to the
 185 west, south, and east, the total volume of the volcano is calculated at $320 \text{ km}^3 \pm 5\%$.

186 On the base of the features of volcanic activities, the mafic to evolved lavas of the early
 187 shield volcano (Eboga volcano and Elengoum Complex) may belong to a single magmatic
 188 series. In return, the activity of flank cones requires a new magma supply. Compared to the
 189 volcano main building (stages 1 to 3), the volume of late flank lavas (stage 4) is very weak
 190 and estimated between 1.5 to 2 km^3 .

191

192 3. Chronological data

193

194 A total of eight lavas are dated by the K/Ar method and six by the $^{40}\text{Ar}/^{39}\text{Ar}$ method
 195 (**Table 1**). All these new age data as well as the previous ones are located on Figures 2, 3, and
 196 4. The $^{40}\text{Ar}/^{39}\text{Ar}$ plateau ages are plotted in **Figure 5**. The complete available
 197 geochronological data for the Manengouba area are given in **Table 2**.

198

The oldest ages are devoted to volcanic rocks emplaced before the formation of the
 199 Manengouba volcano. They concern trachyte and phonolite extrusions related to a thick acidic
 200 volcanic pile at the north-western border of the Manengouba area. Two new Miocene ages,
 201 13.56 ± 0.39 and 7.55 ± 0.18 Ma, are provided for a trachyte extrusion of the Ekomane
 202 Mounts and for a phonolite extrusion of the Bakossi Mounts, respectively (Fig. 4). A slightly
 203 younger age, 11.82 ± 0.47 Ma, was obtained by K/Ar method for a trachyte of the Ekomane

204 area (Table 2; Dunlop, 1983). In addition, a few old mafic lava flows are preserved at the
 205 western lower flanks of the Eocene syenite intrusion of Nlonako, which is the south-eastern
 206 border of the Manengouba. One of these flows of hawaiite composition is dated at 9.37 ± 0.05
 207 Ma (Fig. 3).

208 A particular volcanic activity occurred at the eastern edge of the Manengouba field close to
 209 Ekom. It consists of a rhyolite extrusion a few hundred metres wide (Fig. 2) that we dated at
 210 1.02 ± 0.03 Ma. Relationships with the surrounding basalts are unknown.

211 The oldest Manengouba lava that we analyzed is a trachyte extrusion of the Elengoum
 212 Extrusive Complex, eastern upper flank of Manengouba. It is dated at 0.89 ± 0.02 Ma (Fig. 3).
 213 This age is consistent with that of an Elengoum trachyte formerly dated at 0.70 ± 0.01 Ma
 214 (Table 2; Kagou Dongmo et al., 2001) but geological study demonstrates that the Elengoum
 215 extrusions are late activities of Mount Manengouba. Older ages have been measured for
 216 basaltic lavas constituting the lower flanks of Manengouba and belonging to the early shield
 217 volcano. These basalts are dated at 1.55 ± 0.10 and 0.94 ± 0.06 Ma, south-west of
 218 Nkongsamba in the south-eastern Manengouba field (Table 2; Gouhier et al., 1974; Dunlop,
 219 1983). These basalts are overlain by the Elengoum trachyte flows.

220 All the other and younger ages concern the flank volcanic activity. According to both new
 221 and previous age dating, this activity began at the north-western and northern slopes with the
 222 hawaiite eruptions of Mboassoum and Melong dated at 0.45 ± 0.07 and 0.45 ± 0.04 Ma
 223 respectively (Figs. 2 and 4). It continued with the mugearite eruption of Nyam at 0.40 ± 0.23
 224 Ma, north-western slope, the basanite eruption of Njinjo at 0.40 ± 0.04 Ma (northern slope),
 225 the alkaline basalt eruption of the cone of Manengouba-village at 0.22 ± 0.10 Ma (southern
 226 flank), the hawaiite eruption at 0.20 ± 0.10 Ma on the south-eastern flank, and the basanite
 227 eruption of Ekoh at 0.11 ± 0.03 Ma (eastern flank) (Figs. 2, 3 and 4). A singular extrusive
 228 trachy-phonolite activity at the north-western slope is dated at 0.21 ± 0.02 Ma. In the same
 229 time, hawaiite eruptions occurred inside the Eboga caldera with the formation of two groups
 230 of strombolian cones to the south-east (C1) and the west (C2) and the covering of the caldera
 231 floor (Fig. 3). The C1 flow is dated at 0.36 ± 0.13 and 0.33 ± 0.02 Ma, and the C2 flow is
 232 dated at 0.16 ± 0.07 Ma. This strombolian activity was followed by two phreatomagmatic
 233 explosions that created two maars named “lac de la femme” and “lac de l’homme” (LF, LH,
 234 Fig. 3), and by the Mboriko plug-dome extrusion.

235

236 In summary, the volcanic story of Mount Manengouba is written in four chronological
 237 stages that are sketched in a schematic WNW-ESE cross-section of the volcano in **Figure 6**.

238 Stage 1) The early Manengouba shield volcano was initiated between 1.55 and 0.94 Ma
239 with piling-up of basaltic lava flows. Few data are available concerning these lavas because
240 they have been neglected in the field studies at the benefit of the more attractive strombolian
241 cones and flows at the flanks.

242 Stage 2) Building of the Eboga central volcano took place between 0.94 and 0.89 Ma. The
243 stratovolcano was fed by evolved magma from the main reservoir, in a continuation of the
244 shield volcano activity.

245 Stage 3) Draining of the reservoir and caldera collapse were linked to benmoreitic and
246 trachytic extrusions from 0.89 to 0.70 Ma. Most of the extrusions were emplaced in a SW-NE
247 trending fracture zone of the south-eastern upper slope, namely the Elengoum Extrusive
248 Complex. Some extrusive activities were drained by the caldera sink faults and by the
249 associated sub-circular fault at the north-eastern flank. The total volume of acidic deposits is
250 estimated ca. 20 km³.

251 The meaning of the Ekom rhyolite extrusion dated at 1.02 Ma is unknown. It is impossible
252 to relate this highly evolved product to any Eboga activity. More field work is needed and the
253 age dating must be improved.

254 Stage 4) Renewal of the volcanic activity began at 0.45 Ma and lasted until 0.11 Ma. Lava
255 poured out along flank fractures and inside the caldera. It can be assumed that the main
256 conduit of the initial crater was blocked up by the collapsed rocks of the caldera and acidic
257 intrusions. A small volume of lava reached the caldera but most of the lavas were drained by
258 middle to lower slope fractures. The magma composition evolved from basanites to
259 mugearites and few trachy-phonolites. No time or space distribution of the different rock
260 compositions can be evidenced. Such a volcanic activity requires a renewal of the magma
261 production and the tectonic stress after the emptying of the Eboga reservoir with the extrusion
262 of the last evolved products.

263 Obviously this story is a rough draft of more than one million years of volcanic activity.
264 Very few data are known of the primary shield. No precise dating is available for the Eboga
265 cone building. Relationships between the two collapses of the north-east fault scarp and of the
266 caldera are not clear. It is not sure that the acidic extrusions of Elengoum Complex and the
267 caldera rim are contemporaneous. However, it is clear that the caldera belongs to the
268 Krakatoan or plate/piston type (Cole et al., 2005) and was due to a single main collapse event.
269 According to Acocella (2007), the north-eastern curved scarp can be interpreted as an outer
270 ring fault of the stage four of the evolution of caldera collapse. Regarding the post-caldera
271 activity with extrusion of acidic domes at the caldera rim and further setting of mafic vents on

272 the floor that was covered with basaltic flows, the caldera is classified as type-MS and type-L
273 of Geyer and Marti (2008). We assume that this caldera resulted from the collapse of a strato-
274 cone that culminated circa 2,500 m according to a crater diameter of 1 km (Fig. 6). The depth
275 of the collapse is unknown. For calderas of the same size, measured diameter/subsidence (d/s)
276 ratios range from 5 to 10 (Acocella, 2007). An average value of 7.5 is best estimated referring
277 to many volcanoes of Galapagos, Azores, Canaries, and Cape Verde of similar size and shape
278 (Mitchell-Thomé, 1980; Munro and Rowland, 1996; Caldera Data Base of Geyer and Marti,
279 2008). The initial floor of the caldera was thus ca. 530 m below the present rim. It is doubtful
280 that the acidic domes of the caldera margins took place at such a low level. Owing to their
281 shapes, their bases are less than 50 m deep below the present basaltic floor. These domes
282 probably extruded at the final stage of an acidic activity that has supplied ignimbrite flows
283 filling the caldera (Fig. 6, Stage 3b). The calculated volume of the acidic caldera filling could
284 be estimated between 1.5 and 2 km³.

285

286 **4. Composition of volcanic rocks**

287

288 In agreement with the volcanic story, the volcanic rocks of Manengouba can be attributed
289 to two successive magmatic outputs. The first magma generation produced the primary shield
290 volcano, the Eboga stratovolcano, and the syn- to post-caldera extrusions. It yields the
291 magmatic **Group 1**, displaying a complete series from basanite to trachyte. The second
292 generation was responsible for the formation of the flank cones and flows. It corresponds to
293 the magmatic **Group 2**, evolving from basanite to mugearite and trachy-phonolite. The pre-
294 Manengouba volcanic rocks consist of trachytes and phonolites to the western side, and of
295 hawaiites and mugearites to the eastern side.

296 The mineral compositions have been analyzed with electron probe microanalyzers Cameca
297 SX50 at the University of Orléans and the University of Paris-VI (France). The main results
298 are summarized in **Table 3A and 3B**. Selected analyses of minerals are listed in **Tables 4A to**
299 **4G**. The rocks have been analyzed by ICP-AES and ICP-MS at the analytical laboratory of
300 CRPG-CNRS of Nancy (France). The **Table 5** displays the complete set of chemical analyses.
301 Most of the petrographical data have been acquired during the work for the Ph. D. theses of
302 Kagou Dongmo (1998) and Chakam Tagheu (2006), and were completed in the Professoral
303 thesis of Kagou Dongmo (2006).

304

305 *4.1. Chemical nomenclature*

306

307 Both magmatic groups belong to the under-saturated, alkaline sodic series, although the
 308 intermediate terms overlap with the sodic-potassic limit and the acidic terms are fairly
 309 potassic. In the TAS diagram (La Bas et al., 1986), the Group 1 displays a continuous trend
 310 from basanites to trachytes (**Fig. 7**). The Group 2 evolves from basanites to basaltic trachy-
 311 andesites or mugearites, though one trachy-phonolite dome is pointed out. We use the
 312 nomenclature of the common sodic series and chemical cut based on the Differentiation Index
 313 (DI) of Thornton and Tuttle (1960). This system has the double benefit of regularly dividing
 314 the series and easily naming rocks according to chemical analyses. The mafic rocks evolve
 315 from basanites or alkaline basalts (limit at $\pm 5\%$ of normative nepheline) to hawaiites. A few
 316 mafic lavas are enriched in cumulative olivine and clinopyroxene phenocrysts and are termed
 317 ankaramites. The intermediate lavas are composed of mugearites and benmoreites with no
 318 compositional gap. The more evolved lavas consist of oversaturated trachytes.

319

320 *4.2. Petrographical features of Group 1 lavas*

321

322 The petrographical features of Group 1 lavas are displayed in Table 3A. The more mafic
 323 lavas consist of ankaramites, basanites and alkaline basalts. Their textures are hyalo-microlitic
 324 and more or less porphyritic with 10 to 15 vol.% of olivine, pyroxene, and plagioclase
 325 phenocrysts or microphenocrysts, and magnetite microphenocrysts, sometimes included in
 326 clinopyroxene. The same minerals crystallized in the groundmass in addition with apatite and
 327 ilmenite in a vitreous matrix. The hawaiites have similar textures with varying abundance of
 328 phenocrysts. They are characterized by a higher amount of plagioclase. The mugearites are
 329 hyalo-microlitic and more or less rich in microphenocrysts of olivine, clinopyroxene, and
 330 plagioclase plus Ti-rich amphibole and rare phlogopite. The benmoreites contain few
 331 microphenocrysts of olivine and clinopyroxene, but abundant laths of sodic plagioclase. Clots
 332 of olivine, clinopyroxene, plagioclase, and oxides are frequent. The trachytes show a common
 333 trachytic texture with laths of anorthoclase and microphenocrysts of clinopyroxene.

334 The mineral compositions commonly evolve from mafic to acidic rocks with increasing
 335 Fe/Fe+Mg and Na/Na+Ca ratios. Hereafter, we investigate the composition of the main
 336 magmatic mineral phases. The minerals are depicted following the crystallization order in the
 337 mafic rocks.

338

339 **Olivine**

340 Olivine phenocrysts of basanites and alkaline basalts are moderately zoned. Their Fo
 341 contents range from 81.7 to 77.1, from core to rim. The Fo 78.4-74.1 compositions of
 342 microcrysts share alike the phenocryst rim compositions. Phenocrysts of hawaiites are also
 343 zoned Fo 79.0-69.0, and have the composition of the basalt microcrysts. Microcrysts show
 344 significant iron enrichment: 70.5-57.9. The same pattern is recorded with the phenocrysts of
 345 mugearites and benmoreites having Fo 68.7-65.2 and Fo 67.5-58.3, respectively, and with
 346 their microcrysts having Fo 59.6-55.0 and Fo 55.0-51.3. This is consistent with a continuous
 347 differentiation of a batch of magma involving drastic decrease of the Mg content as a result of
 348 olivine fractionation.

349 A few xenocrysts are recorded in basanites. Their Fo (85.2-84.5) and CaO (0.30-0.25
 350 wt.%) contents indicate that they are inherited from melt rather than entrained mantle
 351 xenocrysts. They probably crystallized in the more primitive magma. Xenocrysts are frequent
 352 in hawaiites. Their Fo (84.5-83.2) and CaO (0.28-0.23 wt.%) contents also indicate that they
 353 are inherited from melt. They have the same composition as the xenocrysts and phenocrysts
 354 of basanites. They then were fractionated from the previous more primitive batch of magma
 355 that has generated the basanites and alkali basalts of the basal shield volcano. Similarly,
 356 mugearites enclose xenocrysts Fo 77.4-74.8 that may have been extracted from the hawaiite
 357 magma. The benmoreites also contain xenocrysts Fo 68.5-66.5 originated from the mugearite
 358 magma. However we cannot discard a post-olivine crystallization modification of the liquid
 359 by crustal assimilation and Mg# decrease (see Geochemical Chapter). We assume that
 360 xenocrysts were removed from the walls of the main magma reservoir where olivines
 361 precipitated with decreasing temperature, causing differentiation of the inner magma
 362 continuously depleted in magnesium.

363 Compositions of olivines are plotted in a Fo% vs. CaO (wt.%) diagram (**Fig. 8A**).
 364 Phenocrysts, microcrysts, as well as xenocrysts crystallized from a related suite of magmas.
 365 The diagram showing the Mg# of lava vs. Fo contents of olivine (**Fig. 9**) allows to distinguish
 366 xenocrysts, phenocrysts and microcrysts. The olivine-liquid equilibrium temperature is
 367 calculated using the equation (4) of Putirka et al. (2007). The temperature decreases from
 368 1300°C for the initial basaltic composition to 1250°C, 1180°C, and 1080°C, while the inner
 369 residual batch of magma evolves from hawaiite to mugearite, and benmoreite composition.
 370 The liquid temperature calculated after the equation (15) of Putirka (2008) decreases from
 371 1230°C to 1190°C, 1100°C, 1085°C, 1070°C, and 1025°C, from basanite to benmoreite.
 372

373 **Magnetite and ilmenite**

374 Magnetite phenocrysts of basanites and alkali basalts are titaniferous and rich in
 375 magnesium and aluminium but poor in chromium. The mole content is dominated by
 376 magnetite, Mg-magnetite or Mg-ferrite and ulvöspinel. The spinel component is limited by
 377 the Al amount. Exceeding Mg substitutes to Fe^{2+} in magnetite. From alkaline basalts to
 378 benmoreites, spinel mole decreases and ulvöspinel slightly increases. Magnetite mole
 379 increases in hawaiites but decreases in benmoreites. Mg-ferrite evolves reversely. Microcrysts
 380 of trachytes are pure Ti-magnetite, devoid of aluminium and magnesium.

381 In **Figure 10**, magnetite compositions display a positive correlation of $\text{Ti} / (\text{Ti} + \text{Al} + \text{Cr})$ and
 382 $\text{Fe}^{2+} / (\text{Fe}^{2+} + \text{Mg})$ ratios from basalts to trachytes due to decreasing Al and Mg contents in the
 383 evolved magmas.

384 Ilmenites are rare in the basaltic rocks. They constitute of more or less abundant
 385 microphenocrysts and microcrysts in hawaiites, mugearites, and benmoreites of the Eboga
 386 middle and upper slopes. From hawaiites to benmoreites, they display a decreasing amount of
 387 the ilmenite component ($0.95 < X'_{\text{ilm}} < 0.87$), calculated after Stormer (1983), and a
 388 concomitant increasing amount of the hematite phase and the $\text{Fe}^{3+}/\text{Fe}^{2+}$ ratio value ($0.12 <$
 389 $\text{Fe}^{3+}/\text{Fe}^{2+} < 0.34$). Ilmenites are limited to few crystals in benmoreites and trachytes of the
 390 Elengoum extrusions and show a composition close to pure ilmenite.

391 Coexisting magnetites and ilmenites have been analyzed in hawaiites, mugearites and
 392 benmoreites. The oxygen fugacity f_{O_2} is estimated from the mole fraction of ulvöspinel X'_{Usp}
 393 in magnetite and of ilmenite X'_{ilm} in ilmenite, calculated after Stormer (1983), and using the
 394 parameters of Andersen and Lindsley (1988). In hawaiites, $\log f_{\text{O}_2}$ averages -13.7 ± 0.5 close
 395 to the $\log f_{\text{O}_2}$ (FMQ) value ($\Delta \log f_{\text{O}_2}$ (FMQ) = 0). In mugearites, $\log f_{\text{O}_2}$ ranges from -13.5 to
 396 12.1 with $\Delta \log f_{\text{O}_2}$ (FMQ) = 0. In benmoreites, $\log f_{\text{O}_2}$ ranges from -10.8 to 10.5 with $\Delta \log f_{\text{O}_2}$
 397 (FMQ) = + 0.5. These results are consistent with an increase of the oxygen fugacity fairly
 398 above the fayalite-magnetite-quartz buffer.

399

400 Clinopyroxene

401 A large set of Group 1 pyroxenes have been analyzed in fourteen samples of basanites to
 402 trachytes including xenocrysts, phenocrysts and microcrysts. To illustrate the various types of
 403 analyzed crystals, pyroxenes are plotted in the temperature vs. $K_D(\text{Fe}-\text{Mg})$ diagram of Putirka
 404 et al. (2003; Figure 5), using the liquid temperature as calculated after equation (15) of
 405 Putirka (2008) and consistent with the olivine-liquid equilibrium temperature (**Fig. 11**). There
 406 is a continuous range of composition of phenocrysts from basanites to benmoreites.
 407 Xenocrysts are rare in basanites but frequent in hawaiites, mugearites, and benmoreites. The

408 analyzed pyroxenes of the more evolved mugearites and of benmoreites are mainly
 409 glomerocrysts from aggregates of olivine, magnetite, and feldspar. The test for equilibrium of
 410 Putirka et al. (2003) and Putirka (2008) (observed pyroxene compositions compared to
 411 calculated compositions) indicates that pyroxenes of the more evolved benmoreites and
 412 trachytes can be phenocrysts.

413 Conventional pyroxene compositions are shown in the Mg-Ca-Fet+Mn diagram (**Fig. 12**).
 414 Two broadly separated clusters are found, one for basanite to benmoreite rocks and one for
 415 trachyte. The first cluster overlaps the diopside-calcic augite boundary. Details of the
 416 composition ranges of the various types of crystals are given in Table 3A. There is a limited
 417 evolutionary trend from phenocrysts of basanite to microcrysts of mugearite with a moderate
 418 decrease in Mg and Ca. The more magnesian crystals are xenocrysts of basanite and hawaiite.
 419 Owing to their Mg-Fe contents, these xenocrysts were inherited from a melt rather than the
 420 mantle. They probably crystallized in the more primitive magma. Most of the phenocrysts of
 421 the less evolved benmoreite are glomerocrysts. One may note that xenocrysts and
 422 glomerocrysts of this benmoreite have the same composition like phenocrysts of hawaiite and
 423 mugearite. This feature reinforces the assumption also given by the olivines that the
 424 xenocrysts were removed from the margins of the main magma reservoir where liquids
 425 differentiated.

426 Pyroxenes of trachytes display a sharply different composition while plotting in the
 427 hedenbergite to calcic augite area. They contain low amount of Na₂O (0.7–1.6 wt.%) despite
 428 belonging to the quadrilateral pyroxenes (100 Di+Hd/Jd+Ac = 86–94). Taking into account
 429 the large compositional gap between the basanites and benmoreite pyroxenes, it can be
 430 concluded that the trachytes were not generated in the main magma reservoir.

431 Additional compositional data of the pyroxenes are given with the Al^{IV} vs.. Al^{VI}, Ti vs..
 432 Al^{VI}, and Ti vs.. Na diagrams (**Fig. 13**). First, there are no pyroxenes inherited from mantle
 433 peridotites. Xenocrysts as well as phenocrysts and microcrysts crystallized from magmas in
 434 the course of the differentiation. Al^{IV}, Al^{VI}, and Ti decrease from basanites to benmoreite in
 435 relationship to the decreasing content of jadeite, esseneite, and Ti-tschermakite at the benefit
 436 of ferrosilite. The Ca-tschermakite mole does not play a significant role. The Ti-Na diagram
 437 indicates that pyroxenes of trachytes crystallized in a distinct batch enriched in Na.

438 To provide clues to the depth of crystallization of the magma, we applied the
 439 clinopyroxene-liquid thermobarometer of Putirka et al. (2003). The barometer is based on
 440 jadeite crystallization and jadeite-diopside + hedenbergite exchange equilibria and is
 441 temperature dependent. It is appropriate for volatile-bearing lava compositions. Here, we used

442 the FeO calculated contents and not the total FeO for rocks and pyroxenes because ferric iron
 443 cannot be neglected in natural samples. The less porphyritic mafic lavas are considered,
 444 discarding cumulate rocks to avoid hazardous subtraction of the olivine phase. We selected
 445 analyses of the core of phenocrysts, yielding a K_D (Fe-Mg) in equilibrium with the lava when
 446 close to the initial liquid composition (0.275; Putirka et al., 2003). Xenocrysts and mantled or
 447 rimed phenocrysts are thus eliminated. Equations of Model A (pressure) and Model B
 448 (temperature) are solved simultaneously. Satisfying results are achieved when both models
 449 yield similar values, with the temperature estimation close to the calculated liquid temperature
 450 according to Putirka (2008). Calculated pressures range from 10.5 to 11.3 ± 1.7 kbars.
 451 Iterative calculations yield somewhat lower P estimations of 9.4 to 10.6 kbars, but with a
 452 temperature 30°C below the calculated liquid temperature. In the continental Cameroon
 453 Volcanic Line, the crustal thickness averages 35.5 km using 1-D shear wave velocity models
 454 (Tokam et al., 2010). In the Manengouba area (station CM15 of Tokam et al., 2010) a more
 455 precise value of 33 km is calculated. With this crustal thickness, the pyroxene barometer
 456 allows locating the crystallization depth between 37 and 39 km in the upper mantle for the
 457 accurate temperature calculation, or between 33.5 and 37 km slightly below the Moho, for the
 458 iterative calculation.

459

460 **Amphibole and mica**

461 Amphiboles are limited to mugearites of the Eboga upper slopes as phenocrysts and
 462 microphenocrysts. They consist of edenite or kaersutite, depending on their increasing content
 463 of TiO_2 . Their $Mg/Mg + Fe^{2+}$ ratios and TiO_2 contents are ranging from 0.86-0.89 and 2.1-2.2
 464 wt.% for edenite, and from 0.66-0.77 and 5.6-6.2 for kaersutite. The Ti-rich amphiboles are
 465 phenocrysts of the more evolved mugearitic lavas.

466 Biotites occur in mugearites and benmoreites of the Eboga upper slopes and comply with a
 467 Ti-rich phlogopite composition ($0.79 < Mg/Mg + Fe^{2+} < 0.83$; $3.5 < TiO_2$ wt % < 3.9).
 468

469 **Feldspar**

470 Phenocrysts and microcrysts of plagioclases are common phases and display a complete
 471 calcic to sodic compositional trend from basanites to evolved lavas. Phenocrysts of basanites
 472 and alkaline basalts are zoned An_{66-60} and microcrysts have the An_{60-51} composition close to
 473 the phenocryst rim. Some lavas contain corroded xenocrysts An_{51-40} , which are inherited
 474 from a former, evolved magma. In the compositional range of hawaiites, phenocrysts vary
 475 from An_{60} to An_{51} and microcrysts from An_{53} to An_{46} . Frequent xenocrysts An_{62-59} originated

476 from a more mafic magma. The same features are depicted in the mugearite and benmoreite
 477 evolutionary trend with An₅₂₋₃₈ and An₄₅₋₃₉ phenocrysts, An₄₀₋₂₈ and An₄₁₋₂₆ microcrysts, and
 478 An₆₁₋₆₀ and An₅₂₋₅₀ xenocrysts. In addition, K-rich microcrysts are discerned in mugearites
 479 (An₂₂₋₁₅, Or₉₋₁₁) and benmoreites (An₂₅₋₁₄, Or₉₋₁₆). In trachytes, phenocrysts and microcrysts
 480 are undistinguishable and consist of anorthoclase Or₃₀₋₃₆.

481

482

483 *4.3. Petrographical features of Group 2 lavas*

484

485 The petrographical features of Group 2 lavas are shown in Table 3B. This group is limited
 486 to basanites, alkali basalts, hawaiites, mugearites, and rare trachy-phonolites, sharing similar
 487 features with equivalent lavas of Group 1, pending more abundant amphiboles and micas. A
 488 sub-holocrystalline, intergranular texture is observed in the ponded lavas and in the Mboriko
 489 plug-dome of the caldera. Mineral compositions are close to those of the Group 1 lavas.

490

491 **Olivine**

492 Olivine phenocrysts are zoned from 83.0 to 78.1. The microcrysts Fo 78.7-72.2 evolve
 493 from the phenocryst rim to slightly iron enriched composition. The phenocrysts of hawaiites
 494 Fo 78.7-70.5 exhibit the composition of the basalt microcrysts. Hawaite microcrysts are iron
 495 enriched: 71.2-65.8. The mugearites show the same trend with the phenocrysts having Fo
 496 77.1-64.4, and the microcrysts: Fo62.9-54.0. This is consistent with a continuous
 497 differentiation of a batch of magma involving drastic decrease of the Mg content as a result of
 498 olivine fractionation.

499 Xenocrysts are also recorded in basanites-alkali basalts (Fo 87.0-86.5) and inherited from a
 500 more primitive magma, hawaiites (Fo 85.0-82.5), inherited from the basanites magma, and
 501 mugearites (Fo 77.9-77.3), inherited from the hawaiite magma. As for Group 1, it is suspected
 502 that xenocrysts were removed from the walls of the main magma reservoir where olivines
 503 precipitated with decreasing temperature, causing differentiation of the residual magma.

504 Compositions of olivines are plotted in a Fo% vs. CaO (wt.%) diagram (Fig. 8B).

505 Phenocrysts, microcrysts, as well as xenocrysts, crystallized from a related suite of magmas.
 506 In the Mg number vs. Fo diagram (Fig. 9), the olivine-liquid equilibrium temperature
 507 decreases from 1310°C for basanite to 1110°C for mugearite. The liquid temperature
 508 decreases from 1260°C to 1085°C.

509

510 **Magnetite and ilmenite**

511 The Group 2 magnetites share similar mineralogical features with those of Group 1. They
 512 consist of microphenocrysts, which are rare in basaltic lavas but common in evolved lavas,
 513 and abundant microcrysts. Compositions are similar to those of Group 1, except for the
 514 chromium content that may reach 12wt % of Cr₂O₃ in basanite microphenocrysts. The mole
 515 content is dominated by magnetite, Mg-magnetite or Mg-ferrite, and ulvöspinel. The spinel
 516 component is limited by the Al amount. Exceeding Mg substitutes to Fe²⁺ in magnetite. From
 517 basanite and alkaline basalt to mugearite, spinel mole decreases and ulvöspinel increases.
 518 Magnetite mole increases in hawaiite but decreases in mugearite. Mg-ferrite evolves
 519 inversely.

520 In Figure 10, magnetite compositions display positive correlation of Ti / (Ti+Al+Cr) and
 521 Fe²⁺ / (Fe²⁺+Mg) ratios from basalt to mugearite due to decreasing Al, Mg, and also Cr
 522 contents in evolved magmas.

523 Ilmenites appear as microphenocrysts and microcrysts in basanites to mugearites. With
 524 evolving lava composition, they display a moderate enrichment in the hematite mole
 525 component ($X'_{ilm} = 0.96$ to 0.94 and Fe³⁺/Fe²⁺ ratio = 0.09 to 0.13).

526 Rare coexisting magnetites and ilmenites have been analyzed in hawaiites. The log f_{O_2}
 527 averages -12.5 ± 0.5 slightly below the log f_{O_2} (FMQ) value ($\Delta \log f_{O_2}$ (FMQ) = - 0.4). This
 528 agrees with the scarcity of early magnetites in mafic magmas.

529

530 **Pyroxene**

531 Group 2 pyroxenes have been analyzed in five basanites and olivine basalts, seven
 532 hawaiites, and four mugearites. As for Group 1 pyroxenes, xenocrysts are rare in basanites,
 533 frequent in hawaiites and abundant in mugearites (Fig. 11). In the Mg-Ca-Fet+Mn diagram
 534 (Fig. 14), a very limited trend is displayed from basanites phenocrysts to mugearite
 535 microcrysts with weak decreasing of Mg and increasing of Fe from phenocrysts and
 536 xenocrysts to microcrysts. As explained for the Group 1 pyroxenes before, xenocrysts,
 537 phenocrysts and microcrysts crystallized from magmas (Fig. 15A). They are only concerned
 538 with Ti-Tchermak, Ca-Tschermak and esseneite mole substitutions. However, the basanite
 539 phenocrysts show an unusual range of composition with either Mg-rich composition (type a)
 540 or apparent Mg-depletion and Ca-enrichment (type b). In the Mg-Ca-Fe ternary diagram, the
 541 enrichment of Ca relative to Mg and Fe (the fassaitic feature) is a consequence of the
 542 contribution of the Tschermak moles to the pyroxene composition. The type b pyroxenes
 543 display higher contents in Ti, Al and Fe³⁺. They plot in a Ti-enriched area in the Fe²⁺ vs. Ti

544 diagram (**Fig. 15B**), where most of the pyroxenes define a common trend with Fe^{2+}
 545 enrichment from mafic phenocrysts and xenocrysts to evolved microcrysts. The high-Ti and
 546 low-Ti pyroxenes are discriminated in the Al vs. Ti diagram (**Fig. 15C**). The Ti and Fe
 547 activities in the magma are controlled by the Ti-magnetite crystallization, depending on the
 548 oxygen fugacity. In the mafic lavas, magnetites and pyroxenes crystallize in the same
 549 thermobarometric range. In most of the cases for the vapor-rich alkaline magmas, magnetite
 550 crystallizes first (high $f\text{O}_2$). Then, the pyroxenes are moderately titaniferous. In the case of
 551 poor magnetite crystallization (lower $f\text{O}_2$), the pyroxenes are enriched in titanium. The
 552 various types of pyroxenes are located at different flank eruptive centres. It is suggested that
 553 these centres were supplied from different magma batches with varying oxygen fugacities.
 554 One may conclude that the late parasitic volcanic activity was originated from separated
 555 reservoirs.

556 According to the clinopyroxene-liquid thermobarometer of Putirka et al. (2003), calculated
 557 pressure ranges from 12.1 to 12.8 ± 1.7 kbars. Assuming a crustal thickness of 33 km (Tokam
 558 et al., 2010), the crystallization depth is located between 42 and 44 km in the upper mantle.
 559 Iterative calculations give temperature values 20°C below the calculated liquid temperature
 560 values, and 11.3 to 12.2 kbars, that is to say 39 to 42 km in depth. In both cases, the
 561 crystallization depth is below the crystallization zone determined for the Group 1 pyroxenes.
 562

563 **Amphibole and mica**

564 Amphiboles are common in Group 2 lavas from basanites to mugearites, in being more
 565 abundant in the evolved rocks. Their composition evolves from edenite to kaersutite with
 566 $\text{Mg}/(\text{Mg} + \text{Fe}^{2+})$ ratios and TiO_2 contents ranging from 0.74 to 0.79 and 2.6 to 3.5 wt.% for
 567 edenite and from 0.67 to 0.79 and 4.6 to 5.8 for kaersutite. They are frequently highly
 568 oxidized in basanites.

569 Biotites coexist with amphibole in displaying a Ti-rich phlogopite composition ($0.76 < \text{Mg}/(\text{Mg} + \text{Fe}^{2+}) < 0.80$; $4.4 < \text{TiO}_2$ wt % < 5.9).

572 **Feldspar**

573 As for Group 1 lavas, phenocrysts and microcrysts show a common compositional trend
 574 from basanites to mugearites. Phenocrysts of basanites and alkaline basalts are An_{66-60} and
 575 microcrysts An_{62-52} . A few rounded xenocrysts An_{43-39} originated from a more evolved
 576 magma are reported in some lavas. Plagioclases of hawaiites and mugearites are An_{60-50} and
 577 An_{55-43} for phenocrysts, and An_{55-45} and An_{47-32} for microcrysts, respectively. Again, rounded

578 xenocrysts An₂₈₋₂₂ originated from a more evolved unknown magma are analyzed in some
 579 lavas. Additional K-rich microcrysts An₁₁₋₆ and Or₃₂₋₄₆ crystallized in the doleritic facies of
 580 the caldera late extrusion.

581

582 *4.4. Petrographical features of the pre-Manengouba lavas*

583

584 The pre-Manengouba volcanic rocks are on one hand, the phonolites and trachytes of
 585 Mounts Bakossi and Ekomane, and on the other hand, a hawaiite and a mugearite flow of the
 586 Nlonako area (Fig. 7).

587 Phonolites and trachytes display a common trachytic texture with laths of sodic feldspars
 588 and microphenocrysts of pyroxenes.

589 The hawaiite is hyalo-microlitic porphyritic with 15% of phenocrysts and
 590 microphenocrysts of abundant plagioclase, olivine Fo₆₄₋₆₈, diopside, phlogopite, magnetite
 591 and rare ilmenite. The mineral composition is close to that of the Manengouba lavas except
 592 for the occurrence of phlogopite that is rare in Manengouba hawaiites. Magnetite is
 593 titaniferous and moderately aluminous and magnesian (18.0 < TiO₂ wt.% < 19.3; 2.9 < Al₂O₃
 594 wt.% < 4.5; 3.2 < MgO wt.% < 4.1; 0.56 < X'_{Usp} < 0.58).

595 The mugearite is hyalo-microlitic porphyritic rich in phenocrysts of plagioclase in addition
 596 with xenocrysts of olivine Fo₈₆₋₇₇ and phenocrysts and microphenocrysts of diopside (41.9 <
 597 XMg% < 44.0; 14.0 < XFet+Mn% < 15.4; 41.3 < XCa% < 43.2), phlogopite, Ti-magnetite
 598 (19.6 < TiO₂ wt.% < 22.4). 2.3 < Al₂O₃ wt.% < 4.2; 3.7 < MgO wt.% < 4.7; 1.1 Cr₂O₃ wt.% <
 599 1.4; 0.61 < X'_{Usp} < 0.67), and ilmenite (X'_{Ilm} = 0.91; Fe³⁺/Fe²⁺ = 0.23). The xenocystic olivine
 600 is inherited from a more mafic magma. Coexisting magnetite and ilmenite indicate a log f_{O2}
 601 ranges from -11.1 to 9.9 with Δ log f_{O2} (FMQ) = - 0.1.

602 According to the clinopyroxene-liquid thermobarometer of Putirka et al. (2003), calculated
 603 pressure ranges from 6.0 to 5.2 kbars, locating the crystallization level in the lower to middle
 604 crust.

605

606 **5. Geochemistry**

607

608 *5.1. Geochemical features*

609

610 A total of 29 analyses have been carried out for the magmatic Group 1, 42 for the Group 2,
 611 and 2 for the Ekom rhyolite. Four analyses concern the western pre-Manengouba acidic lavas,
 612 and four the eastern pre-Manengouba mafic lavas.

613 The Group 1 lavas display a complete differentiation trend from basanite to trachyte. The
 614 Group 2 lavas evolve from basanite to trachy-phonolite. Both groups display similar trends on
 615 the MgO wt.% vs. oxides covariation diagrams (**Fig. 16A**). Decrease of MgO and increase of
 616 all the oxides in the more mafic lavas are related to olivine fractionation. Below 8 MgO wt.%,
 617 additional fractionation of clinopyroxene in alkali basalt and hawaiite is evidenced by
 618 decreases of CaO and FeO. The decreasing TiO₂ in hawaiite indicates fractionation of Ti-
 619 bearing oxides. The sudden decrease of Al₂O₃ in mugearite points to plagioclase fractionation.
 620 Possible fractionation of apatite may have occurred in benmoreite according to P₂O₅ loss. In
 621 the minor element covariation diagrams (**Fig. 16B**), the compatible elements Cr and Ni
 622 display heavy depletion from mafic to evolved rocks due to Mg-Fe phase fractionation.
 623 Vanadium decreases in hawaiites, like titanium, indicating an oxide fractionation. Strontium
 624 exhibits a wide range of contents betraying the heterogeneity of Group 2 lavas of the late
 625 magmatic activity. However, Sr-decreases in hawaiite and mugearite are linked to plagioclase
 626 fractionation. The incompatible elements Rb, Ba, Ga, Zr, Hf, Nb, Ta, Y, Pb, Th, U, and the
 627 REE exhibit common enrichments from basanite to trachyte, while some trachytes and the
 628 rhyolite are depleted by volatile transfer. Again, variations in the Zr, Hf, Nb, Ta, and the light
 629 rare earth element contents in basalt and hawaiite indicate a somewhat heterogeneity of
 630 primitive magmas.

631 The incompatible element signatures are illustrated with the chondrite-normalized and
 632 MORB-normalized diagrams (**Figs. 17 and 18**). The stages 1 and 2 lavas display rare earth
 633 element (REE) enriched patterns with (La/Yb)_N ratios ranging from 9.6 to 24.5 and 163 to 332
 634 rare earth amounts. Compared to MORB, these lavas point to increasingly enriched trends
 635 from high field strength to large ion lithophile elements, except Sr and K which are poorly
 636 enriched. But the heavy rare earth elements are depleted indicating a different source than the
 637 MORB one.

638 The stage 3 evolved lavas are similarly enriched ($10.8 < (\text{La/Yb})_N < 23.3$), except the
 639 rhyolite ($3.0 < (\text{La/Yb})_N < 7.3$) with 259 to 589 rare earth element amounts. The trachytes
 640 exhibit significant negative Eu anomalies ($0.8 < \text{Eu/Eu}^* < 0.1$). The MORB normalized
 641 patterns show higher amounts of incompatible trace elements compared to mafic lavas, and
 642 significant negative anomalies resulting from fractional crystallization that increases in
 643 importance from benmoreite to trachyte. The Ti and P negative anomalies are due to

644 fractional crystallization of oxides and apatite, respectively. Ba, Sr, in addition with Eu
 645 negative anomalies in trachyte comply with feldspar fractionation.

646 The stage 4 lavas (Group 2) display the same patterns as the stages 1 and 2 lavas. From
 647 basanite to trachy-phonolite, the $(La/Yb)_N$ ratios range from 9.5 to 25.6, and rare earth
 648 abundances from 117 to 379. They are poorly enriched in Sr and K, and depleted in the heavy
 649 rare earth elements. The lava with the lowest enrichment in incompatible elements is an
 650 olivine and pyroxene-rich basanite (CT110) of a thick flow that ponded inside the caldera in
 651 form of a temporary lava lake. This relative depletion is due to olivine and pyroxene
 652 cumulation. The basanite to trachy-phonolite evolved patterns are compatible with fractional
 653 crystallization as shown by the major element covariation diagrams (Fig. 16). Most of the
 654 mugearites exhibit moderate P and Ti negative anomalies denoting apatite and oxides
 655 fractionation. A few mugearites have weak positive anomalies of Ba and Eu, compatible with
 656 feldspar cumulation. The trachy-phonolite is enriched in incompatible elements but depleted
 657 in Eu, Ba, P, and Ti. These features denote fractional crystallization of feldspar, apatite and
 658 oxides.

659 The pre-Manengouba mafic lavas share close geochemical compositions with the lavas of
 660 Manengouba. The hawaiites show positive anomalies of Eu and Ba due to feldspar
 661 accumulation. The trachytes and phonolites show signs of fractional crystallization of
 662 feldspar, apatite and oxides as evidenced by negative anomalies of Eu, Ba, P, and Ti. In
 663 addition, the phonolites are depleted in the middle rare earth elements (MREE) and Ta that
 664 may suggest an amphibole fractionation because amphibole has a greater compatibility of the
 665 MREE (Zack et al., 1997).

666 The Manengouba mugearites and benmoreites contain a few biotite and amphibole that
 667 may have played in the differentiation processes. To test this effect, Rb, Ba, K, and Sr
 668 covariation diagrams have been drawn, as well as a Ba/Rb vs. Rb/Sr diagram as suggested by
 669 Furman et al. (2006). The differentiation trends for these elements are dominated by the
 670 feldspar fractionation. Indeed, the lithophile element variations indicate a limited role or no
 671 role for biotite and amphibole. In return, Th and Pb contents in many trachytes attest for a
 672 crustal contribution. Lower Ce/Pb is typical of crustal assimilation. A Ce/Pb value lower than
 673 20 is commonly retained (Rogers et al., 1992; Furman et al., 2007). In the Th/Pb vs. Ce/Pb
 674 diagram (**Fig. 19**), all the trachytes plot below this value, as well as the Bakossi phonolites.
 675

676 *5.2. Source characteristics and degree of partial melting*

677

678 The mafic lava compositions are used to determine the parental magma composition and
 679 the mantle source characteristics, excluding cumulate facies. The closest rocks to primary
 680 mantle melts are CT46 and EB20 for the Manengouba main cone building (Stages 1 and 2,
 681 magmatic Group 1) and for the late activity (Stage 4; magmatic Group 2) owing to their MgO
 682 and Ni contents (**Fig. 20**). CT46 is a basal thick flow of the early shield volcano cropping out
 683 at the lower southern flank. EB20 is an intra-caldera flow that filled the caldera basin before
 684 the ultimate explosive maar activity. We retain the mafic lavas of magmatic Group 1 (5
 685 analyses) and of Group 2 restricted to MgO greater than 6 wt.% (15 analyses). Two
 686 neighbouring olivine fractionation trends can be defined from the partial melting area drawn
 687 after Class et al. (1994). The primary melt composition averages 9 to 10 wt.% of MgO and
 688 250 to 290 ppm of Ni.

689 The MORB normalized trace element diagram of the selected mafic lavas show that the
 690 Manengouba profiles are identical to that of the average OIB of Sun and McDonough (1989)
 691 (**Fig. 21**). A similar enriched mantle source can be assumed, as shown by the Ta/Yb vs.
 692 Th/Yb diagram (**Fig. 22A**). However, distinct Zr/Hf and Nb/Ta ratios (**Fig. 22B**) prove that
 693 the sub-Manengouba mantle source is different of that of OIBs, and also of MORBs and
 694 continental basalts. This source is suspected to have high Zr/Hf ratio of 46.2 and low Nb/Ta
 695 ratio of 13.75 averaging the CT46 and EB20 values. Considering the set of mafic lavas,
 696 Nb/Ta remains constant with variable Zr/Hf, a feature of OIB and MORB fields that is usually
 697 explained by pyroxene fractionation (Pfänder et al., 2007 and 2012). However, the
 698 petrographical relationships show that the Zr/Hf ratio decreases with Zr from mafic to
 699 evolved lavas. Such a trend cannot be explained by pyroxene fractionation. Similar high
 700 Zr/Hf ratios are known from the eastern and western branches of the East African rift, but
 701 with high Nb/Ta ratios as in the Kenya rift (Rogers et al., 2006). Nevertheless, lavas of the
 702 Virunga area, north of the Lake Kivu, display Nb/Ta ratios close to those of the Manengouba,
 703 as well as high Zr/Hf ratios (Rogers et al., 1992, 1998; Platz et al., 2004; Chakrabarti et al.,
 704 2009). The Zr/Hf trend can be due to enrichment of the source region by metasomatic fluid as
 705 suggested by Dupuy et al. (1992) or to infiltration of carbonatite-rich fluids according to
 706 Rudnick et al. (1993).

707 The rare earth element abundances and ratios are commonly used to constrain the mantle
 708 source characteristics. The relative heavy rare earth element depletion with a $(\text{Tb}/\text{Yb})_{\text{N}}$ ratio
 709 lower than 1.8 is indicative of a garnet-bearing source at the melting zone (e.g. Rooney et al.,
 710 2010). The higher ratio for CT46 (23.48) compare to EB20 (2.17) indicates a more amount of
 711 garnet in the source that must be deeper. The same result is given by the $(\text{Dy}/\text{Yb})_{\text{N}}$ ratio

712 compared to the La/Yb_N ratio used by Rogers et al. (2006) to calculate the garnet content of
713 the melting primitive mantle. In that case, the garnet content is 8% for CT46 and 4% for
714 EB20. If the source is enriched, contents are slightly lowered. Mineral composition and
715 degree of partial melting can be approached with La/Sm and Sm/Yb values. On the one hand,
716 the La/Sm ratio is a function of the degree of melting and provides information on the source
717 chemical composition. On the other hand, the Sm/La ratio discriminates the spinel or garnet-
718 bearing source, and provides an estimation of the degree of melting once the La/Sm ratio is
719 defined. In the La vs. La/Sm and La/Sm vs. Sm/Yb diagrams (Fig. 23), melt curves are drawn
720 for spinel-lherzolite, garnet-lherzolite, and a 50:50 mixture of spinel- and garnet-lherzolite.
721 Modal compositions of spinel-lherzolite (olivine 53%, OPX 27%, CPX 17%, spinel 3%) and
722 garnet-lherzolite (olivine 60%, OPX 20%, CPX 10%, garnet 10%) are after Kinzler (1997)
723 and Walter (1998). Mineral/melt partition coefficients for basaltic liquids are after the
724 compilation of Rollinson (1993). The mantle array is defined by the depleted MORB mantle
725 (DMM composition from Salters and Stracke, 2004) and primitive mantle (PM after Sun and
726 McDonough, 1989) trend. In the La vs. La/Sm diagram (Fig. 23A), the mafic lavas plot in the
727 melting trends between 2% and 5% of partial melting. The trends deal with an enriched
728 source and a La/Sm ratio value between 2 and 2.5. A more precise composition of the source
729 is calculated by the inversion method. However, we know the precision of such calculation is
730 illusive whatever the used formulae and the batch melting scenarios, because of the
731 uncertainty of the bulk partition coefficients that highly control the results (notwithstanding
732 the heterogeneity of the source). In the La/Sm vs. Sm/Yb diagram (Fig. 23B), the lavas plot
733 slightly above (CT46) or close (EB20) to the 50:50 spinel-garnet lherzolite melting trend.
734 Partial melting degrees average 3% for CT46 and 6% for EB20. On the base of the estimated
735 enriched source composition, the garnet content of the source could be 7% for CT46 and 3%
736 for EB20 according the (Dy/Yb)_N ratio compared to the La/Yb_N ratio (Rogers et al., 2006).
737 Assuming a 6 to 8 times enrichment of chondritic abundances suggested by the La/Sm and
738 Sm/Yb ratios and a La value averaging 2.2, the melting degrees are calculated on the base of
739 the above indicated data. Unrealistic values were obtained due to excess garnet in the source.
740 A second calculation was done with the garnet peridotite composition and bulk partition
741 coefficients of Salters and Longhi (1999), and Salters et al. (2002). Partial melting degrees of
742 3% for CT46 and of 6% for EB20 agree with the La/Sm-Sm/Yb diagram.
743 It can be concluded that melting took place in the spinel to garnet transition zone located at
744 70 to 90 km and around 25 kb at the melt temperature values (O'Neill, 1981; Schilling et al.
745 2005). The less abundant garnet and the higher partial melting degree in the late and parasitic

746 volcanic activity (EB20, Stage 4) indicate uprising of the melting column to the upper part of
 747 transition zone. It has been noted that the magmatic signature is sodic (Fig. 7) and poor in
 748 potassium. Rb is moderately enriched and the Ba/Rb and Rb/Sr ratios are low. These chemical
 749 features are compatible with an amphibole-bearing source rather than with a mica-bearing
 750 source. Limit of the stability fields of amphibole and phlogopite locates around 25 to 30 kb in
 751 the lithospheric mantle (e.g. Class and Goldstein, 1997). It is consistent with the location of
 752 the Manengouba magma source in the spinel-garnet transition zone and in the amphibole
 753 field. The existence of an amphibole-bearing upper mantle beneath the CVL is supported by
 754 the sampling of amphibole-spinel-garnet ultramafic xenoliths in volcanoes of Ngaoundéré,
 755 Lake Nyos, Oku, and Mount Cameroon (Lee et al. 1996; Temdjam et al., 2004; Matsukage
 756 and Oya, 2010; Temdjam, 2012). After Marzoli et al. (2000), trace element patterns agree with
 757 an amphibole-bearing source for Sr-rich mafic rocks of the Bambouto volcano. Moreover, an
 758 amphibole-bearing lherzolite composition is advocated by Yokoyama et al (2007) for the
 759 lithospheric mantle beneath Mt Cameroon on the base of U-series disequilibria relationships.
 760 It is straightforward to postulate that the same lithospheric mantle locates beneath Mt
 761 Manengouba.

762

763 *5. 3. Isotopic data*

764

765 A total of nine samples of Manengouba have been analyzed by Halliday et al. (1988; 1990)
 766 for Sr, Nd, and Pb isotope ratios. Most of these samples are basaltic lavas from the flank
 767 cones. One basalt belongs to the old shield. The ratio variations between old and recent lavas
 768 are in the range of the analytical reproducibility. In addition to these data, we analyzed seven
 769 samples of Manengouba including the Ekom rhyolite and the trachy-phonolite of the late
 770 north-western flank activity, and three samples of the north-western Essom trachyte, the
 771 Bakossi phonolite, and the eastern basaltic substratum (**Table 6**). A representative mafic lava
 772 of Manengouba, the rhyolite, the trachy-phonolite and the Essom trachyte have been selected
 773 for lead isotope analyses.

774 In the Manengouba lavas, initial $^{87}\text{Sr}/^{86}\text{Sr}$ ratios display a restricted range from 0.7030 to
 775 0.7032 with low radiogenic Sr values close to the Enriched Depleted MORB Mantle in
 776 **Figure 24A** (E-DMM of Workman and Hart, 2005). Initial $^{143}\text{Nd}/^{144}\text{Nd}$ ratios expressed as
 777 ϵNd are from +4.4 to +6.8, the lowest value pertaining to the trachy-phonolite. The values of
 778 the late Miocene hawaiite of the substratum are close to those of the Manengouba and may
 779 have originated from similar source. As it is common, trachyte, phonolite, and rhyolite are

780 enriched in radiogenic Sr resulting from crustal assimilation as shown by the chemical data.
 781 In return, such process has not affected the trachy-phonolite that simply derived from mafic
 782 parent by fractional crystallization. The Pb isotopic compositions of Manengouba are
 783 radiogenic with $19.6 < ^{206}\text{Pb} / ^{204}\text{Pb} < 20.2$, $15.6 < ^{207}\text{Pb} / ^{204}\text{Pb} < 15.7$, and $39.3 < ^{208}\text{Pb} / ^{204}\text{Pb} <$
 784 39.9. They straddle to the FOZO component redefined by Stracke et al. (2005) and plot near
 785 the NHRL (Northern Hemisphere Reference Line at 1.77 Ga; Hart, 1984) with a Th/U ratio
 786 averaging 4 (**Fig. 24B and C**). The Ekom rhyolite and the Essom trachyte, thought to be
 787 contaminated by continental crustal material are less radiogenic. It should be noted that the
 788 rhyolite was fractionated in U and Pb (Th/U = 21).

789 The Manengouba shares same geochemical and isotopic features with all the Cenozoic
 790 volcanoes of the Cameroon Volcanic Line (CVL), and particularly the high $^{208}\text{Pb} / ^{204}\text{Pb}$ ratio
 791 commonly related to the HIMU component. Along the CVL, one distinctive isotopic feature
 792 is reported with slightly higher $^{206}\text{Pb} / ^{204}\text{Pb}$ ratio for the continental-ocean boundary (cob)
 793 volcanoes (Mount Cameroon, Etinde, Bioko) compared to the continental sector and the
 794 oceanic sector (Halliday et al., 1988). The Manengouba isotope values are similar to those of
 795 the continental part.

796

797 *5.4. Search for the source components*

798

799 The Cameroon Volcanic Line is characterized by depleted values of the Sr and Nd isotopic
 800 ratios with Pb isotopic radiogenic enrichments. There are no prominent geochemical
 801 discrepancies between the recent lavas of both the continental and oceanic sectors. On these
 802 bases, it was suggested that the lavas have been derived from sub-lithospheric sources which
 803 were contaminated by melts of an (HIMU) enriched fossil plume head emplaced during
 804 continental breakup in the present Gulf of Guinea area (Halliday et al., 1990; Lee et al., 1994).
 805 Alternatively, the lead isotope peculiarities may be explained by contamination of primary
 806 asthenospheric melts by melting of sub-continental mantle hosted the FOZO component
 807 (Rankenburg et al., 2005). For addressing these models to the Manengouba magmatic sources,
 808 we collected the Sr, Nd, and Pb isotopic values of the CVL from Halliday et al. (1988; 1990),
 809 Lee et al. (1994), Marzoli et al. (2000), Rankenburg et al. (2005), Yokoyama et al. (2007),
 810 Nkouandou et al. (2008), Nkouathio et al. (2008), Wandji et al. (2009), Mbassa et al. (2012)
 811 and Kamgang et al. (2013). We limited the data set to mafic lavas and recalculated the initial
 812 ratios. Plotted results are outlined in $^{87}\text{Sr} / ^{86}\text{Sr}$ vs. $^{143}\text{Nd} / ^{144}\text{Nd}$, $^{206}\text{Pb} / ^{204}\text{Pb}$ vs. $^{207}\text{Pb} / ^{204}\text{Pb}$, and
 813 $^{206}\text{Pb} / ^{204}\text{Pb}$ vs. $^{208}\text{Pb} / ^{204}\text{Pb}$ diagrams (Fig. 24A, B and C).

814 Lavas of the CVL are distributed in six groups bearing on distinct isotopic features (Fig.
 815 1): 1) Biu and Mandara lavas in the northern end display both the highest depleted and the
 816 highly radiogenic terms. They also show a wide compositional range to enriched and less
 817 radiogenic terms. Rankenburg et al. (2005) explain these features with two contamination
 818 processes of the primary magmas: addition of an “enriched” (they mean “radiogenic”) sub-
 819 continental lithospheric melts and addition of bulk continental crust. 2) Ngaoundéré lavas in
 820 the north-eastern faulted branch are moderately enriched and moderately radiogenic with an
 821 enrichment trend. 3) Lavas of the middle continental sector of the CVL (Oku, Bamenda,
 822 Bambouto, Manengouba and Tombel) share similar moderately enriched and moderately
 823 radiogenic isotope composition, but with a significant enrichment trend suggesting an EM1
 824 contribution according to Sr/Nd and lead isotope covariation diagrams (Fig. 24). 4) Towards
 825 the continent-ocean boundary (COB), lavas of Mount Cameroon, Etinde, and Bioko Island are
 826 characterized by high radiogenic lead isotope ratios that are due to young fractionation in
 827 U/Pb within the upper mantle according to correlatives with Sr, Nd, Pb, and Hf isotopic
 828 values (Ballentine et al., 1997). They are fairly enriched with low Nd isotopic ratios 5) At the
 829 islands of Principe and São Tomé, lavas are quite similar with highly to moderately
 830 radiogenic lead isotopes and significantly depleted terms. 6) The Pagalu Island lavas point out
 831 unradiogenic lead ratios and somewhat enriched terms.

832 The salient isotopic features are best discriminated in the Sr vs.. $^{208}\text{Pb}/^{204}\text{Pb}$ diagram (**Fig.**
 833 **24D**). The data fields are explained by varying contribution of three components. First, two
 834 components: a depleted component (DC) and a radiogenic component (RC) define the
 835 primary magmas, because they are prominent in the most primitive lavas. DC and RC
 836 resemble the ‘A’ and ‘B’ components of Rankenburg et al. (2005). Then, the different
 837 primary magmas evolve along orthogonal paths owing to increasing contribution of an
 838 enriched component (EC) that could be the ‘CC’ component of Rankenburg et al. (2005).

839 The geochemical data reveal that there are no doubts that **the depleted component**
 840 originated from asthenospheric upwelling that occurred all along the CVL as shown by swell
 841 elevation related to thermal thinning (Poudjon-Djomani et al., 1995, 1997; Meyers et al.,
 842 1998). **The radiogenic component** was suspected to belong to a plume head. One main
 843 plume (St Helena type) or several small plumes (Halliday et al., 1988; Lee et al. 1994, 1996)
 844 have fed the upper mantle in the past and contaminated the magmatic sources with the HIMU
 845 component. However, the highest radiogenic composition of the cognate magmatic
 846 megacrysts reflecting the source composition may be representative of the radiogenic end-
 847 member after Rankenburg et al. (2005). This end-member is more enriched than the HIMU

848 end-member (higher Sr ratio and lower Nd ratio) and is close to the richest Nd and Pb ratio
 849 domain of the FOZO compositional field (Stracke et al., 2005). In the African plate Cenozoic
 850 volcanism, FOZO is ubiquitous in the continental part: Hoggar-Aïr, Darfur, Ethiopia, Kenya,
 851 and Tanzania (Paslick et al., 1995; Franz et al., 1999; Aït-Hamou et al., 2000; Rogers et al.,
 852 2000; Kieffer et al., 2004; Furman et al., 2006; Pik et al., 2006) as well as in the oceanic part:
 853 Canary, Madeira, and Cape Verde (Gerlach et al., 1988; Hoernle et al., 1991; Halliday et al.,
 854 1992; Millet et al., 2008). The continental sectors are located in the Mesoproterozoic and
 855 Neoproterozoic mobile belts where many ocean plate subduction and collision processes have
 856 taken place. It can thus be inferred that the continental lithosphere, unlike the oceanic
 857 lithosphere, registered multiple metasomatic events and not only a single Mesozoic
 858 enrichment from a hypothetical mantle plume. Consequently, we assume that the radiogenic
 859 component is a common feature of the African continental lithosphere particularly in the Pan-
 860 African belts. This radiogenic orogenic-related source is more realistic than the plume source
 861 unless to invoke numbers of plume and unsustainable plume tracks. No plume trail can be
 862 evidenced below the CVL (Pasyanos and Nyblade, 2007). Late Pliocene to present day
 863 volcanic activities emplaced simultaneously all along the CVL, from Biu to the middle
 864 continental sector, the Mount Cameroon, and the Pagalu Island (Fitton and Dunlop, 1985; Lee
 865 et al., 1994; Kagou Dongmo et al., 2010).

866 **The enriched component** resembles the ‘CC’ component of Rankenburg et al. (2005)
 867 deriving either from the sub-continental lithospheric mantle (SCLM) or the continental crust,
 868 both being characterized by high Sr isotope ratio and low Nd and Pb isotope ratios (Fig. 24).
 869 On the base of osmium isotope values, Rankenburg et al. (2005) promote the contamination
 870 with continental crust for Biu lavas. Similar isotopic trends are shown by mafic lavas of the
 871 middle continental CVL, namely in the Bambouto and Bamenda volcanoes (Nkouathio et al.,
 872 2008; Kamgang et al., 2013). These volcanoes and the Manengouba have produced abundant
 873 evolved lavas, phonolites, trachytes, and rhyolites. These acidic lavas display geochemical
 874 evidences of crustal contamination, as shown for the Manengouba trachytes (this work, Fig.
 875 19). In return, no clear geochemical witnesses of crustal assimilation are seen in the mafic
 876 lavas. Except for the Os isotope ratio (after Rankenburg et al., 2005), the commonly used
 877 isotope ratios (Sr, Nd, Pb) are unable do discriminate alone between the crust and the
 878 enriched mantle contributions. In the lack of crustal-related geochemical arguments, we
 879 support the hypothesis that enriched trends to EC in mafic lavas are due to the contribution
 880 either of an EM1-like inherent component of the sub-continental lithosphere or to any recent
 881 enrichment linked to pre-rifting processes. Indeed, clear evidences of sub-continental

882 lithosphere enrichment are given by the numerous Cretaceous to Eocene alkaline volcano-
 883 plutonic complexes distributed all along the CVL from the Atlantic coast to the Lake Chad
 884 (Déruelle et al., 1991; Vicat et al., 2002) and emplaced before the Miocene to present-day
 885 volcanoes.

886 A latent question is how the lavas of the oceanic portion of the CVL can be so enriched in
 887 continental lithosphere source component if both the radiogenic and the enriched components
 888 (RC and EC) belong to the sub-continental lithospheric mantle? The oceanic localization
 889 would favour asthenospheric origin of the source components. Indeed, the Pagalu lavas are
 890 unradiogenic but significantly enriched (Fig. 24D). Many authors have invoked the
 891 entrainment of delaminated continental fragments in the oceanic domain during the
 892 continental breakup (e.g. Rankenburg et al., 2005). First, we must specify that the CVL
 893 oceanic volcanoes straddle NE-SW fracture zones in the continuation the continental fault
 894 network predating the breakup (Meyers et al., 1998). Second, these faults have fed a
 895 continental margin volcanic activity: the Pointe Gombé volcano and the Banc du Loiret lava
 896 plateau (Cornen et al., 1993). This activity was contemporaneous with the early activity of the
 897 São Tomé and Pagalu volcanoes and shares the same petrographical, chemical, and isotopic
 898 composition (Cornen et al., 1993). Third, these faults are associated with post-Pan-African
 899 late Neoproterozoic intrusions of alkaline syenites and carbonatites that give evidences of
 900 metasomatic enrichment of the sub-continental mantle. The São Tomé volcano straddles the
 901 Kribi fracture zone that joints the on-land northern Kribi Fault. The Pagalu volcano straddles
 902 the Fang fracture zone that extends the Kribi Fault. The Fang fracture zone has fed the Pointe
 903 Gombé and Banc du Loiret volcanics in the time of the Pagalu volcano building. The Kribi
 904 Fault is linked to the Kribi alkaline syenite recently investigated and dated at 590 Ma (Nsifa et
 905 al., 2013). Giving all these consistent volcano-tectonic relationships, there is no doubt that
 906 magmas of the CVL oceanic volcanoes merely originated from the metasomatized sub-
 907 continental mantle. The source of Pagalu is limited to DC+EC (Fig. 24D) and is located in the
 908 Congo Craton margin lithospheric mantle and outside the Pan-African realm that may explain
 909 its unradiogenic composition.

910

911 **6. Conclusion**

912

913 The Mount Manengouba is a great volcano of the middle continental sector of the
 914 Cameroon Volcanic Line (CVL). It culminates at 2411 m and covers 500 km². It emplaced in

915 a graben between two N 30°E trending normal faults. It straddles a N 50°E fracture zone
 916 suggesting a right-lateral transtensional setting.

917 New mapping of the volcanic formations led to distinguish four chronological units from
 918 the early shield volcano to the late flank lavas. The volume of the volcano is calculated at 320
 919 km³ ± 5%. The final flank activity volume is weak and estimated between 1.5 to 2 km³. The
 920 four chronological stages dated by 5 published K/Ar ages and 11 new K/Ar and ⁴⁰Ar/³⁹Ar
 921 measurements are as follow: 1) piling-up of the early Manengouba shield volcano between
 922 1.55 and 0.94 Ma, 2) building of the Eboga stratovolcano between 0.94 and 0.89 Ma, 3)
 923 caldera collapse and acidic Elengoum extrusions between 0.89 and 0.70 Ma, and 4) intra-
 924 caldera and flank activity between 0.45 and 0.11 Ma. New K/Ar ages are also provided for
 925 pre-Manengouba volcanic activities: 13.56 Ma and 7.55 Ma for a trachyte and a phonolite of
 926 the western border, and 9.37 Ma for a hawaiite of the south-eastern substratum of the
 927 Manengouba shield.

928 The Eboga caldera belongs to the Krakatoan or plate-piston type and resulted from a single
 929 collapse. It is classified in the type-Ms and type-L of Geyer and Marti (2008).

930 The volcanic rocks are attributed to two magmatic outputs. The first and main magma
 931 generation produced the shield volcano, the stratovolcano, and the syn- to post-caldera
 932 extrusions, displaying a complete series from basanites to trachytes (magmatic Group 1). The
 933 second magma production is limited to the late intra-caldera and flank activity evolving to
 934 basanites to trachy-phonolite (magmatic Group 2). Olivine and pyroxene thermobarometers
 935 locate the magmatic reservoir between 37 and 39 km in the upper mantle for the Group 1
 936 lavas, and between 42 and 44 km for the Group 2 lavas. Similar depth, 35 to 44 km, has been
 937 obtained with the same method for the magma chamber of basanites of Mount Cameroon by
 938 Wandji et al. (2009). Trachytes were generated in a secondary crustal reservoir because of the
 939 large gap in the pyroxene composition. Magmatic series evolve with medium to low pressure
 940 fractional crystallization of olivine, pyroxene, oxides, feldspar, and apatite. Significant crustal
 941 assimilation is evidenced in trachytes. The parental magma composition is estimated close to
 942 the average OIB composition. But, distinct Zr/Hf and Nb/Ta ratios prove that the magma
 943 source registered a distinct metasomatic enrichment event. The magma of the main volcano
 944 was generated with 3 to 6% of partial melting of a moderately enriched source (6 to 8 times
 945 enrichment of chondrite abundances) containing 3 to 7% of garnet. Melting of the
 946 Manengouba source took place in the spinel to garnet transition zone located at 70 to 90 km
 947 and around 25 kb at the melt temperature values. The magma of the late flank activity resulted
 948 from a slightly higher partial melting from a less garnet-rich source that indicates uprising of

949 the melting column to the upper part of transition zone. The low Rb contents and low Ba/Rb
 950 and Rb/Sr ratios are compatible with an amphibole-bearing source.

951 Some Sr, Nd, and Pb isotope new data of the Manengouba rocks and neighbouring lavas
 952 complete the data of Halliday et al. (1988, 1990). They comply with those of the middle
 953 continental sector of the CVL. Sr and Nd isotope values plot near the enriched depleted
 954 MORB mantle source with a moderate enrichment. Pb isotope values are somewhat
 955 radiogenic in plotting in the FOZO compositional field, close to the NHRL, and show a short
 956 enrichment trend. The evolved lavas are unradiogenic and registered crustal assimilation.
 957 Review of the isotope data of mafic lavas of the whole CVL led to discriminate three source
 958 components: a depleted component related to the asthenospheric upwelling, a radiogenic
 959 component that we attributed to the lithosphere of the Neoproterozoic mobile belt
 960 contaminated during orogenic events, and an enriched component of the lithosphere possibly
 961 related to pre-rifting magmatic processes linked to the Cretaceous to Eocene intrusions of
 962 alkaline volcano-plutonic complexes distributed all along the CVL.

963

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976

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1258
 1259 **Caption**

1260
 1261 **Fig. 1.** A) The Mount Manengouba and the great volcanoes in the Cameroon Line. B) Main
 1262 structural features of the Mt Manengouba are on a Digital Elevation Model (Image Landsat 7
 1263 ETM Satellite Imagery, data set: SRTM, Producer: USGS/GLCF, Date 2000, ID 045-76
 1264 Cameroon). Nk, Nkongsamba town. N, Nlonako, and K, Koupé, Eocene syenitic alkaline
 1265 intrusions.

1266
 1267 **Fig. 2.** Geological map of the Manengouba. Main units of the volcano: 1) stacked lavas of the
 1268 middle and low slopes of the shield, 2) the Eboga stratovolcano, 3) the Elengoum Extrusive
 1269 Complex, and 4) the flank cones and flows of the late parasitic activity.

1270
 1271 **Fig. 3.** Detailed map of the Eboga caldera, Elengoum complex and south-eastern low flank
 1272 showing the pre-Manengouba flows preserved along the Nlonako syenite massif. Most of the
 1273 age data locate in this area. DS, phreatomagmatic crater of Djeu Sey; LF, maar of the “Lac de
 1274 la femme”; LH, maar of the “Lac de l’homme”; MB, plug-dome of Mbouroukou; SCSV,
 1275 supra-caldera strombolian volcanic complex.

1276

1277 **Fig. 4.** Detailed map of the north-western low slope showing the age data of flank activity and
 1278 of the pre-Manengouba trachy-phonolite extrusions of Ekomane and Bakossi.

1279

1280 **Fig. 5.** Ar/Ar plateau ages.

1281

1282 **Fig. 6.** Sketch of the four stages of the volcanic activities.

1283

1284 **Fig. 7.** Nomenclature of the Manengouba lavas. A, SiO_2 vs. $\text{Na}_2\text{O} + \text{K}_2\text{O}$ diagram after Le
 1285 Bas et al. (1986). B, DI vs. normative quartz or nepheline diagram displaying the under-
 1286 saturation of the series. DI, Differentiation Index of Thornton and Tuttle (1960).

1287

1288 **Fig. 8.** Fo% vs. CaO (wt.%) diagram of olivines: A) Group 1; B) Group 2. In both groups,
 1289 phenocrysts, microcrysts, as well as xenocrysts crystallized from a related suite of magmas.

1290

1291 **Fig. 9.** Mg# vs. Fo diagram of whole rock and olivine compositions. The Mg number is
 1292 calculated assuming a wt.% $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio of 0.15. The olivine-liquid equilibrium
 1293 temperature is calculated after the equation (4) of Putirka et al. (2007). The liquid temperature
 1294 is calculated after the equation (15) of Putirka (2008). The pressure of the main magma
 1295 chamber is estimated at 1 GPa according to the clinopyroxene-liquid thermobarometer of
 1296 Putirka et al. (2003) and Putirka (2008). Distribution coefficient $K_D = (\text{XOl}/\text{FeO})/(\text{XLiq}/\text{FeO})$
 1297 $\times (\text{XLiq}/\text{MgO})/(\text{XOl}/\text{MgO})$ of Roeder and Emslie (1970). Same symbols as for Figure 8.

1298

1299 **Fig. 10.** $\text{Fe}^{2+}/(\text{Fe}^{2+}+\text{Mg})$ vs. $\text{Ti} / (\text{Ti}+\text{Al}+\text{Cr})$ diagram of Ti-magnetites of Groups 1 and 2.
 1300 Projections from the multicomponent spinel prism (Haggerty, 1976). From basanite to
 1301 hawaiite, magnetites display decreasing Ti and Fe^{2+} ratios due to decreasing Al and Mg
 1302 contents in Group 1, and decreasing Cr, Al and Mg contents in Group 2. Mugearite and
 1303 benmoreite phenocrysts are similar to those of hawaiite, while microcrysts are depleted in Al
 1304 and Mg. Trachyte microcrysts only contain Fe and Ti.

1305

1306 **Fig. 11.** $10^4/T(\text{K})$ vs. $\ln (K_D^{\text{Fe-Mg}})$ of pyroxenes, according to Putirka et al. (2003), for
 1307 illustrating the distribution of phenocrysts in equilibrium with liquids, microcrysts of the
 1308 evolved groundmasses, and xenocrysts inherited from more mafic magmas crystallized in the
 1309 magma chamber. Pyroxenes of the more differentiated benmoreites and trachytes could be

1310 either xenocrysts or phenocrysts of a liquid that was disturbed by post-pyroxene
1311 crystallization processes. K_D is calculated assuming a wt.% $\text{Fe}_2\text{O}_3/\text{FeO}$ ratio of 0.15 for
1312 liquids and using the pyroxene calculated FeO contents.

1313

1314 **Fig. 12.** Mg-Ca-Fet+Mn diagram of Group 1 pyroxenes.

1315

1316 **Fig. 13.** Al^{IV} vs. Al^{VI} , Ti vs. Al^{VI} , and Ti vs. Na diagrams. Symbols as for Figure 12.

1317

1318 **Fig. 14.** Mg-Ca-Fet+Mn diagram of Group 2 pyroxenes.

1319

1320 **Fig. 15.** Al^{IV} vs. Al^{VI} , Fe^{2+} vs. Ti, and Al vs. Ti diagrams. Symbols as for Figure 14.

1321

1322 **Fig. 16 A and B.** MgO wt.% vs. major and minor elements covariation diagrams. Symbols as
1323 for Figure 7.

1324

1325 **Fig. 17.** Chondrite normalized rare earth element patterns for A) stages 1 and 2 lavas, B) stage
1326 3 lavas, C) stage 4 lavas, and D) pre-Manengouba lavas. Normalizing values after
1327 McDonough and Sun (1995).

1328

1329 **Fig. 18.** N-MORB normalized incompatible trace element patterns for A) stages 1 and 2
1330 lavas, B) stage 3 lavas, C) stage 4 lavas, and D) pre-Manengouba lavas. Normalizing values
1331 after Sun and McDonough (1989).

1332

1333 **Fig. 19.** Th/Pb vs. Ce/Pb diagram showing the crustal assimilation in the Manengouba
1334 trachytes and in the Bakossi phonolites. Bulk continental crust after Rudnick and Gao (2003).

1335

1336 **Fig. 20.** Covariation of MgO and vs. Ni for Group 1 (Stages 1 and 2) and Group 2 (Stage 4)
1337 mafic lavas. Partial melting area of primitive mantle drawn after Class et al. (1994). CT46 and
1338 EB20 are close to the primitive mantle melts with, respectively Mg# of 60 and 63 and Ni
1339 (ppm) of 222 and 238. Parental magmas may average 9 to 10 wt.% of MgO and 250 to 290
1340 ppm of Ni in resulting from about 5% of partial melting. The two almost similar fractional
1341 trends of the two magmatic groups extend until 15 to 20% of olivine fractionation.

1342

1343 **Fig. 21.** N-MORB normalized incompatible trace element patterns restricted to mafic lavas of
 1344 the Manengouba main building (Group 1, stages 1 and 2) and of the late parasitic activity
 1345 (Group 2, stage 4). OIB pattern after Sun and McDonough (1989).

1346

1347 **Fig. 22. A)** Ta/Yb vs. Th/Yb diagram. **B)** Zr/Hf vs. Nb/Ta diagram.

1348 PM, N-MORB, E-MORB, and OIB from Sun and McDonough (1989); DMM from Salters
 1349 and Stracke (2004); chondritic values from Münker et al. (2003); MORB, OIB, and
 1350 continental basalts fields after Pfänder et al. (2007); Kenya rift and Virunga fields drawn with
 1351 the data of Rogers et al. (1992, 1998, 2006), Platz et al. (2004), and Chakrabarti et al. (2009).

1352

1353 **Fig. 23. A)** La vs. La/Sm and **B)** La/Sm vs. Sm/Yb diagrams for determining the enrichment
 1354 of the source and the partial melting degrees of the mantle source. The La vs. La/Sm diagram
 1355 suggests a source enrichment similar to that of the E-MORB and a degree of partial melting
 1356 between 2% and 5% on the lherzolite melt curves. Once this source is admitted, the La/Sm vs.
 1357 Sm/Yb diagram suggests a spinel-garnet lherzolite source composition with a 50:50 mixture
 1358 of spinel and garnet. Modal compositions of spinel-lherzolite (olivine 53%, OPX 27%, CPX
 1359 17%, spinel 3%) and garnet-lherzolite (olivine 60%, OPX 20%, CPX 10%, garnet 10%) are
 1360 after Kinzler (1997) and Walter (1998). Mineral/melt partition coefficients for basaltic liquids
 1361 are after the compilation of Rollinson (1993). Primitive Mantle (PM), N-MORB, and E-
 1362 MORB compositions are from Sun and McDonough (1989). Depleted MORB mantle (DMM)
 1363 from Salters and Stracke (2004).

1364

1365 **Fig. 24. A, B, and C,** $^{86}\text{Sr}/^{87}\text{Sr}$ vs. $^{143}\text{Nd}/^{144}\text{Nd}$, $^{206}\text{Pb}/^{204}\text{Pb}$ vs. $^{207}\text{Pb}/^{204}\text{Pb}$, and $^{206}\text{Pb}/^{204}\text{Pb}$ vs.
 1366 $^{208}\text{Pb}/^{204}\text{Pb}$ diagrams (time corrected values) for the Manengouba and pre-Manengouba lava
 1367 analyses of this study completed by the Manengouba mafic lava analyses of Halliday et al.
 1368 (1988 and 1990). These data are compared with the whole data for mafic lavas of the
 1369 Cameroon Volcanic Line plotted in six fields from north to south: Biu-Mandara, Ngaoundéré,
 1370 middle continental shields (Oku, Bamenda, Bambouto, Manengouba, and Tombel), continent-
 1371 ocean boundary (Mt Cameroon, Etinde, Bioko), Principe-São Tomé, and Pagalu. See text for
 1372 the references. DMM, HIMU, PREMA, BSE, EM1, and EM2 after O’Nions et al. (1977),
 1373 Zindler and Hart (1986), Rollinson (1993); FOZO after Stracke et al. (2005); EDMM after
 1374 Workman and Hart (2005).

1375 **D**, $^{86}\text{Sr}/^{87}\text{Sr}$ vs. $^{206}\text{Pb}/^{204}\text{Pb}$ diagram for showing the three theoretical components of
 1376 magmatic sources of the Cameroon Volcanic Line. DC, depleted component; RC, radiogenic
 1377 component; EC, enriched component. Explanation of the trends, see text.

1378

1379 **Table 1.** New radiochronological data. K/Ar analyses were done by H. Bellon at the
 1380 Laboratory of Geochronology of the “Université de Bretagne Occidentale”, Brest, France.
 1381 Ar/Ar analyses were done by G. Ruffet at the Laboratory of Geochronology of the
 1382 “Université de Rennes 1”, Rennes, France. CNRS (CNRS/INSU) UMR 6118, Géosciences
 1383 Rennes, 35042 Rennes Cedex, and Université de Rennes I, Géosciences Rennes, 35042
 1384 Rennes Cedex, France. Age calculation was carried on using the constants of Steiger and
 1385 Jäger (1977). Data, parameters used for Ar/Ar calculations (isotopic ratios measured on K, Ca
 1386 and Cl pure salts; mass discrimination; atmospheric argon ratios; J parameter; decay
 1387 constants) and reference sources are available in the supplementary data repository.

1388

1389 **Table 2.** Report of the available chronological data for the Manengouba area distributed in
 1390 age groups.

1391

1392 **Table 3.** Petrographical composition of Group 1 (A) and Group 2 (B) lavas.
 1393 X'USP, apparent mole fraction of ulvöspinel according to Stormer (1983).

1394

1395 **Table 4.** Representative chemical analyses of minerals: A, Olivine; B, Magnetite; C, Ilmenite.
 1396 D, Clinopyroxene; E, Amphibole; F, Mica; G, Feldspar.
 1397 Alk-B, alkaline basalt; Ank, ankaratrite; Bn, benmoreite; Bs, basanite; Na-Bs, sodic basanite;
 1398 H, hawaiite; M, mugearite; Tr, trachyte.

1399

1400 **Table 5.** Chemical analyses of the rocks. Petrographical facies as for Table 4 plus Na-H,
 1401 sodic hawaiite; Ph, phonolite; Rh, rhyolite; Tr-Ph, trachy-phonolite. DI (Differentiation
 1402 Index) after Thornton and Tuttle (1960). Analyses by ICP-AES (major elements) and ICP-MS
 1403 (minor and trace elements) at the Centre de Recherches Pétrographiques et Géochimiques
 1404 (CRPG, CNRS) of Nancy, France.

1405

1406 **Table 6.** Sr, Nb, and Pb isotope data. MS measurements (VG Sector 54 TIMS) at the
 1407 Université libre of Bruxelles (Belgium). Analyst: Daniel Demaiffe.

1408

KPB-Table 1
K/Ar analyses

			K ₂ O (wt%)	⁴⁰ Ar* %	⁴⁰ Ar* /g (10 ⁻⁷ cm ³)	³⁶ Ar Exp (10 ⁻⁹ cm ³)	Age (Ma) ± 1 σ
CT107	Tr	Essom peak	5.31	86.5	23.29	1.24	13.56 ± 0.39
CT103	Ph	W-Bangem	5.26	82.5	12.82	0.93	7.55 ± 0.18
CT155	Rh	Ekom	4.46	41.6	1.46	0.7	1.02 ± 0.03
CT108	H	Mboassoum (flank activity)	1.25	6.1	0.18	0.94	0.45 ± 0.07
CT47	H	Melong (flank activity)	1.38	9.55	0.2	0.51	0.45 ± 0.04
CT52	M	Nyam-Enyandong (flank activity)	2.19	1.6	0.28	6.27	0.40 ± 0.23
CT105	T-P	W-Bangem (flank activity)	4.12	11.9	0.28	0.71	0.21 ± 0.02
CT55	Bs	Ekoh (flank activity)	1.7	3.5	0.059	1.662	0.11 ± 0.03

⁴⁰Ar/³⁹Ar analyses

			Plateau Age ± 1 σ	Isochron Age ± 1 σ	MSWD	(⁴⁰ Ar/ ³⁶ Ar) _i ± 1 σ	
KBT5	H	Nkongsamba, NE-Nlonako	9.37 ± 0.05	9.31 ± 0.63	1.24	305.8 ± 13.9	
PTE6	Tr	Elengoum	0.89 ± 0.02	0.88 ± 0.05	1.2	305.7 ± 5.6	
KEB19	H	Eboga caldera SE floor	flow from cone # 1	0.46 ± 0.05	0.36 ± 0.13	0.05	301.5 ± 4.0
KEB32	H	Eboga caldera SE floor	flow from cone # 1	0.33 ± 0.02	0.34 ± 0.03	0.99	292.7 ± 6.1
KTC1	B	W-Ndougue	flank activity	0.24 ± 0.07	0.22 ± 0.10	2.68	284.4 ± 5.1
KEB33	H	Eboga caldera NW floor	flow from cone # 2	0.14 ± 0.04	0.16 ± 0.07	0.49	291.5 ± 4.8

KPB-Table 2

Pre-Manengouba volcanic rocks						
Northwestern and eastern borders						
Extrusions of trachyte and phonolite and mafic lava flows						
CT107	Tr	13.56 ± 0.39	Essom peak	K4		
C54	Tr	11.82 ± 0.47	Ekomane	K2		
KBT5	H	9.37 ± 0.05	Nkongsamba	A1		
CT103	Ph	7.55 ± 0.18	W-Bangem	K4	x	
	B	1.55 ± 0.10	Nkongsamba area	K1		
	C55	B	0.94 ± 0.06	Ndoungué	K2	
Mafic shield volcano and strato-volcano building (Early Manengouba and Eboga) (stages 1)						
MANENGOUBA						
Acidic extrusions (Elengoum Extrusive Complex) (stage 3)						
CT155	Rh	1.02 ± 0.03	NE-Ekom	K4		
PTE6	Tr	0.89 ± 0.02	Central Elengoum	A1		
PT3	Tr	0.70 ± 0.01	South Elengoum	K3		
Post-caldera and flank activities (stage 4)						
CT108	H	0.45 ± 0.07	Mboassoum	K4		
CT47	H	0.45 ± 0.04	Melong	K4		
CT52	M	0.40 ± 0.23	Enyandong	K4		
C52	B	0.40 ± 0.04	Njinjo	K2		
KEB19	H	0.36 ± 0.13	Eboga caldera	A1		
KEB32	H	0.33 ± 0.02	Eboga caldera	A1		
KTC1	B	0.22 ± 0.10	W-Ndougùè	A1		
CT105	TP	0.21 ± 0.02	W-Bangem	K4		
SP5	H	0.20 ± 0.10	SE-Nkongsamba	K3		
KEB33	H	0.16 ± 0.07	Eboga caldera	A1		
CT55	Bs	0.11 ± 0.03	Ekoh	K4		

(K1) Gouhier et al. (1974)

(K2) Dunlop (1983)

(K3) Kagou et al. (2001)

(K4) new K/Ar data

(A1) new $^{40}\text{Ar}/^{39}\text{Ar}$ data

Table 3A

Magmatic Group # 1

Group 1	Basanite - Alkali Basalt	Hawaiite
Xenocrysts	0.50%	1%
Olivine	$84.5 < \text{Fo} < 85.2$ $0.25 < \text{CaO wt\%} < 0.30$	$83.2 < \text{Fo} < 84.5$ $0.23 < \text{CaO wt\%} < 0.28$
Clinopyroxene	$40.5 < \text{XMg\%} < 40.8$ $13.6 < \text{XFet+Mn\%} < 13.8$ $45.4 < \text{XCa\%} < 45.9$	$40.5 < \text{XMg\%} < 43.4$ $12.4 < \text{XFet+Mn\%} < 14.1$ $42.4 < \text{XCa\%} < 46.7$
Feldspar	An 51-40	An 62-59
Phenocrysts and Microphenocrysts	10 - 15 %	10 - 15 %
Olivine	$77.1 < \text{Fo} < 81.7$ $0.19 < \text{CaO wt\%} < 0.25$	$69.0 < \text{Fo} < 79.0$ $0.22 < \text{CaO wt\%} < 0.29$
Magnetite	$17.1 < \text{TiO}_2 \text{ wt\%} < 18.6$ $4.2 < \text{Al}_2\text{O}_3 \text{ wt\%} < 4.8$ $4.9 < \text{MgO wt\%} < 6.6$ $0.48 < \text{X'Usp} < 0.51$	$17.2 < \text{TiO}_2 \text{ wt\%} < 20.9$ $1.8 < \text{Al}_2\text{O}_3 \text{ wt\%} < 5.2$ $2.2 < \text{MgO wt\%} < 4.6$ $0.50 < \text{X'Usp} < 0.64$
Ilmenite	no accurate analyses	$\text{X}'\text{Ilm} = 0.95$ $\text{Fe}^{3+}/\text{Fe}^{2+} = 0.12$
Clinopyroxene	$39.9 < \text{XMg\%} < 44.0$ $13.5 < \text{XFet+Mn\%} < 14.8$ $41.8 < \text{XCa\%} < 46.5$	$39.4 < \text{XMg\%} < 46.0$ $11.7 < \text{XFet+Mn\%} < 16.6$ $41.6 < \text{XCa\%} < 47.5$
Amphibole		
Biotite		
Feldspar	An 66-60	An 60-51
Microcrysts		
Olivine	$74.1 < \text{Fo} < 78.4$ $0.16 < \text{CaO wt\%} < 0.28$	$57.9 < \text{Fo} < 70.5$ $0.19 < \text{CaO wt\%} < 0.44$
Magnetite	$18.3 < \text{TiO}_2 \text{ wt\%} < 20.7$ $1.9 < \text{Al}_2\text{O}_3 \text{ wt\%} < 2.4$ $4.0 < \text{MgO wt\%} < 4.9$ $0.50 < \text{X'usp} < 0.61$	$18.3 < \text{TiO}_2 \text{ wt\%} < 21.1$ $2.3 < \text{Al}_2\text{O}_3 \text{ wt\%} < 3.0$ $1.8 < \text{MgO wt\%} < 2.0$ $0.57 < \text{X'usp} < 0.64$
Ilmenite		$\text{X}'\text{ilm} = 0.93$ $\text{Fe}^{3+}/\text{Fe}^{2+} = 0.18$
Clinopyroxene	$38.9 < \text{XMg\%} < 45.4$ $14.5 < \text{XFet+Mn\%} < 17.8$ $40.2 < \text{XCa\%} < 45.8$	$39.6 < \text{XMg\%} < 42.8$ $14.7 < \text{XFet+Mn\%} < 15.8$ $41.7 < \text{XCa\%} < 44.6$
Feldspar	An 60-51	An 53-46

Table 3B

Magmatic Group # 2

Group 2	Basanite - Alkali Basalt	Hawaiite	Mugearite
Xenocrysts	0.50%	1%	2%
Olivine	$87.0 < \text{Fo} < 86.5$ $0.25 < \text{CaO wt\%} < 0.20$	$85.0 < \text{Fo} < 82.5$ $0.21 < \text{CaO wt\%} < 0.19$	$77.9 < \text{Fo} < 77.3$ $0.20 < \text{CaO wt\%} < 0.18$
Pyroxene	$41.1 < \text{XMg\%} < 47.9$ $10.5 < \text{XFet+Mn\%} < 13.6$ $41.6 < \text{XCa\%} < 46.0$	$41.1 < \text{XMg\%} < 45.2$ $9.2 < \text{XFet+Mn\%} < 15.0$ $43.0 < \text{XCa\%} < 46.3$	$38.1 < \text{XMg\%} < 42.8$ $12.0 < \text{XFet+Mn\%} < 15.3$ $41.7 < \text{XCa\%} < 48.6$
Feldspar	An 43-39		An 28-22
Phenocrysts and Microphenocrysts	10 - 15 %	5 - 10%	5 - 10%
Olivine	$83.0 < \text{Fo} < 78.1$ $0.30 < \text{CaO wt\%} < 0.20$	$78.7 < \text{Fo} < 70.5$ $0.37 < \text{CaO wt\%} < 0.21$	$77.1 < \text{Fo} < 64.4$ $0.32 < \text{CaO wt\%} < 0.16$
Magnetite	$13.3 < \text{TiO}_2 \text{ wt\%} < 17.9$ $4.8 < \text{Al}_2\text{O}_3 \text{ wt\%} < 8.0$ $5.0 < \text{MgO wt\%} < 5.5$ $3.5 < \text{Cr}_2\text{O}_3 < 12.3$ $0.60 < \text{X'usp} < 0.65$	$16.8 < \text{TiO}_2 \text{ wt\%} < 22.1$ $2.7 < \text{Al}_2\text{O}_3 \text{ wt\%} < 5.1$ $3.5 < \text{MgO wt\%} < 5.5$ $0.1 < \text{Cr}_2\text{O}_3 < 2.7$ $0.53 < \text{X'usp} < 0.69$	$17.2 < \text{TiO}_2 \text{ wt\%} < 21.8$ $2.7 < \text{Al}_2\text{O}_3 \text{ wt\%} < 5.7$ $2.7 < \text{MgO wt\%} < 4.6$ $0.54 < \text{X'usp} < 0.67$
Ilmenite	$\text{X}'\text{ilm} = 0.96$ $\text{Fe}^{3+}/\text{Fe}^{2+} = 0.09$	$\text{X}'\text{ilm} = 0.96$ $\text{Fe}^{3+}/\text{Fe}^{2+} = 0.10$	$\text{X}'\text{ilm} = 0.94$ $\text{Fe}^{3+}/\text{Fe}^{2+} = 0.13$
Pyroxene	$33.8 < \text{XMg\%} < 48.5$ $11.2 < \text{XFet+Mn\%} < 17.6$ $38.6 < \text{XCa\%} < 50.2$	$40.0 < \text{XMg\%} < 44.9$ $11.9 < \text{XFet+Mn\%} < 17.1$ $41.1 < \text{XCa\%} < 45.1$	$37.2 < \text{XMg\%} < 43.6$ $11.9 < \text{XFet+Mn\%} < 16.9$ $42.1 < \text{XCa\%} < 48.1$
Amphibole	$0.74 < \text{Mg/Mg+Fe}^{2+} < 0.79$ $3.7 < \text{TiO}_2 \text{ wt\%} < 4.7$	$0.67 < \text{Mg/Mg+Fe}^{2+} < 0.72$ $5.2 < \text{TiO}_2 \text{ wt\%} < 5.8$	$0.67 < \text{Mg/Mg+Fe}^{2+} < 0.79$ $2.6 < \text{TiO}_2 \text{ wt\%} < 5.8$
Biotite			$0.76 < \text{Mg/Mg+Fe}^{2+} < 0.80$ $4.4 < \text{TiO}_2 \text{ wt\%} < 5.9$
Feldspar	An 66-60	An 60-50	An 55-43
Microcysts			
Olivine	$78.7 < \text{Fo} < 72.2$ $0.40 < \text{CaO wt\%} < 0.16$	$71.2 < \text{Fo} < 65.8$ $0.35 < \text{CaO wt\%} < 0.27$	$62.9 < \text{Fo} < 54.0$ $0.42 < \text{CaO wt\%} < 0.26$
Magnetite	$16.7 < \text{TiO}_2 \text{ wt\%} < 20.1$ $3.3 < \text{Al}_2\text{O}_3 \text{ wt\%} < 5.4$ $3.4 < \text{MgO wt\%} < 5.1$ $0.51 < \text{X'usp} < 0.63$	$20.5 < \text{TiO}_2 \text{ wt\%} < 22.9$ $0.3 < \text{Al}_2\text{O}_3 \text{ wt\%} < 1.9$ $0.3 < \text{MgO wt\%} < 3.0$ $0.48 < \text{X'usp} < 0.64$	$21.2 < \text{TiO}_2 \text{ wt\%} < 23.2$ $1.5 < \text{Al}_2\text{O}_3 \text{ wt\%} < 2.8$ $1.7 < \text{MgO wt\%} < 3.2$ $0.55 < \text{X'usp} < 0.70$
Ilm		$\text{X}'\text{ilm} = 0.93$ $\text{Fe}^{3+}/\text{Fe}^{2+} = 0.15$	
Px	$37.2 < \text{XMg\%} < 43.4$ $10.6 < \text{XFet+Mn\%} < 17.5$ $41.3 < \text{XCa\%} < 46.7$	$37.3 < \text{XMg\%} < 42.4$ $14.5 < \text{XFet+Mn\%} < 21.8$ $40.7 < \text{XCa\%} < 45.2$	$35.1 < \text{XMg\%} < 36.8$ $19.2 < \text{XFet+Mn\%} < 21.2$ $43.7 < \text{XCa\%} < 44.8$
F	An 62-52	An 55-45	An 47-32 An 11-6, Or 32-46

Table 4. Selected chemical analyses of minerals. A, Olivine

Manengouba, stage 1

#	MA2b	CT45	CT45	CT45	ML2	ML2
Petrographical facies	Bs	alk-B	alk-B	alk-B	H	H
Mineral type	xenocryst	phenocryst	microcryst	microcryst	xenocryst	phenocryst
SiO ₂	40.82	39.09	38.20	38.92	40.39	39.45
TiO ₂	0.04	0.00	0.05	0.08	0.03	0.03
Al ₂ O ₃	0.03	0.00	0.00	0.00	0.08	0.04
FeO	14.29	16.87	19.32	21.98	14.86	19.66
MnO	0.19	0.27	0.47	0.52	0.22	0.27
MgO	46.81	42.79	40.21	39.13	46.13	42.00
CaO	0.30	0.19	0.16	0.28	0.23	0.22
NiO		0.08	0.00	0.42		
Total	102.48	99.29	98.41	101.33	101.94	101.67
Si	0.996	0.999	0.998	1.000	0.994	0.995
Ti	0.001	0.000	0.001	0.002	0.001	0.001
Al	0.001	0.000	0.000	0.000	0.002	0.001
Fe ²⁺	0.292	0.360	0.422	0.472	0.306	0.415
Mn	0.004	0.006	0.010	0.011	0.005	0.006
Mg	1.702	1.630	1.566	1.498	1.692	1.580
Ca	0.008	0.005	0.004	0.008	0.006	0.006
Ni	0.000	0.002	0.000	0.009	0.000	0.000
Total	3.003	3.001	3.001	2.999	3.005	3.003
% Fo	85.21	81.65	78.36	75.60	84.50	78.97
% Fa	14.79	18.35	21.64	24.40	15.50	21.03

Table 4. Selected analyses of minerals. B, Magnetite

#	Manengouba, stage 1				Manengouba, stage 2			
	Petrographical facies		MA2b Bs	MA2b Bs	ML2 H	ML2 H	NS2 H	Eb11 M
	Mineral type	phenocryst	microcryst	phenocryst	microcryst	phenocryst	phenocryst	microcryst
SiO ₂	0.01	0.00	0.05	0.03		0.02	0.05	0.04
TiO ₂	17.51	18.59	20.85	19.25		17.23	16.21	17.11
Al ₂ O ₃	4.83	4.15	5.17	2.30		1.83	2.47	2.02
Cr ₂ O ₃	0.03	0.03	0.08	0.06		0.02	0.12	0.01
FeO	69.24	68.05	67.73	73.12		73.75	77.34	75.59
MnO	0.56	0.38	0.50	0.71		0.46	0.67	0.85
MgO	6.25	6.55	4.54	1.78		2.22	1.16	0.47
Total	98.43	97.75	98.92	97.25		95.51	98.02	96.09
Si	0.003	0.000	0.014	0.009		0.004	0.015	0.012
Al	1.578	1.367	1.706	0.797		0.642	0.850	0.715
Ti	3.650	3.906	4.390	4.254		3.862	3.558	3.863
Fe ³⁺	7.111	6.814	5.468	6.664		7.621	7.977	7.532
Fe ²⁺	8.939	9.088	10.391	11.306		10.766	10.902	11.449
Mg	2.582	2.728	1.895	0.780		0.986	0.505	0.210
Mn	0.131	0.090	0.119	0.177		0.115	0.166	0.216
Cr	0.007	0.007	0.018	0.014		0.004	0.028	0.002
Total	24.000	24.000	24.000	24.000		24.000	24.000	24.000

Table 4. Selected analyses of minerals. C, Ilmenite

	Manengouba, stage 2			Manengouba, stage 3		
#	NS2	EB30	Eb11	Eb11	EL4	Eb17
Petrographica l facies	H	M	M	M	Bn	Bn
Mineral type	microcryst	phenocryst	phenocryst	microcryst	phenocryst	microcryst
SiO ₂	0.00	0.00	0.00	0.00	0.00	0.00
TiO ₂	49.71	50.17	49.66	48.22	48.92	51.12
Al ₂ O ₃	0.36	0.14	0.20	0.43	0.47	0.04
Cr ₂ O ₃	0.00	0.00	0.03	0.00	0.00	0.00
FeO	41.92	42.46	45.39	48.20	44.44	44.69
MnO	0.63	0.77	0.94	0.81	0.64	1.38
MgO	4.89	4.01	3.42	1.81	5.45	0.86
CaO	0.03	0.03	0.03	0.03	0.05	0.05
Total	97.54	97.58	99.67	99.50	99.97	98.14
Si	0.000	0.000	0.000	0.000	0.000	0.000
Al	0.021	0.008	0.012	0.025	0.027	0.002
Ti	1.854	1.885	1.834	1.804	1.770	1.962
Fe ³⁺	0.263	0.218	0.315	0.359	0.424	0.072
Fe ²⁺	1.476	1.556	1.549	1.647	1.364	1.836
Mg	0.361	0.299	0.250	0.134	0.391	0.065
Mn	0.026	0.033	0.039	0.034	0.026	0.060
Cr	0.000	0.000	0.001	0.000	0.000	0.000
Ca	0.001	0.002	0.002	0.002	0.003	0.003
Total	4.002	4.000	4.001	4.003	4.002	3.998

Table 4. Selected analyses of minerals. D, Pyroxenes

Manengouba, stage 1

#	MA2B	MA2B	MA2B	MA2B	MA2B	ML2
Petrographical facies	Na-Bs	Na-Bs	Na-Bs	Na-Bs	Na-Bs	H
Mineral type	xenocryst	phenocryst	phenocryst	microcryst	microcryst	xenocryst
SiO ₂	47.39	48.98	49.27	50.27	52.45	47.45
TiO ₂	2.27	2.03	2.02	1.06	0.77	2.12
Al ₂ O ₃	7.13	5.49	4.75	3.37	1.90	5.87
FeO	8.17	8.18	8.10	8.33	10.58	7.84
Cr ₂ O ₃	0.04	0.00	0.18	0.00	0.00	0.04
MnO	0.17	0.16	0.20	0.27	0.56	0.26
MgO	13.86	14.25	14.62	15.16	13.93	13.94
CaO	21.44	21.03	21.25	18.65	20.94	21.59
Na ₂ O	0.65	0.70	0.33	0.56	0.52	0.57
K ₂ O	0.01	0.00	0.00	0.00	0.02	0.00
Total	101.13	100.82	100.72	97.66	101.67	99.68
Si	1.733	1.796	1.814	1.899	1.928	1.761
Al ^{IV}	0.267	0.204	0.186	0.101	0.072	0.239
T	2.000	2.000	2.000	2.000	2.000	2.000
Al ^{VI}	0.040	0.033	0.020	0.049	0.010	0.018
Ti ^{VI}	0.062	0.056	0.056	0.030	0.021	0.059
Fe ³⁺	0.147	0.108	0.073	0.032	0.057	0.141
Cr	0.001	0.000	0.005	0.000	0.000	0.001
Fe ²⁺	0.090	0.125	0.152	0.189	0.237	0.091
Mg	0.660	0.678	0.694	0.699	0.675	0.689
M1	1.000	1.000	1.000	1.000	1.000	1.000
Fe2+	0.013	0.019	0.024	0.042	0.031	0.011
Mg	0.096	0.101	0.108	0.154	0.089	0.082
Mn	0.005	0.005	0.006	0.009	0.017	0.008
Ca	0.840	0.826	0.838	0.755	0.825	0.859
Na	0.046	0.050	0.024	0.041	0.037	0.041
K	0.000	0.000	0.000	0.000	0.001	0.000
M2	1.001	1.000	1.000	1.000	1.000	1.001
Mg %	44.34	44.42	44.01	46.19	40.74	44.33

Table 4. Selected analyses of minerals. E, Amphibole

Manengouba, stage 2			Manengouba,		
#	EB11	Eb10	Eb10	Eb10	EK1C
Petrographical facies	M	M	M	M	H
Mineral type	nicrophenocrys Edenite	phenocryst Kaersutite	phenocryst Kaersutite	phenocryst Kaersutite	phenocryst Kaersutite
SiO ₂	45.40	40.84	40.24	39.59	39.53
TiO ₂	2.10	6.03	5.85	6.16	5.20
Al ₂ O ₃	6.71	13.03	12.34	13.65	12.85
Cr ₂ O ₃	0.00	0.02	0.00	0.05	0.00
FeO	10.66	11.24	11.11	10.63	11.55
MnO	0.39	0.21	0.22	0.17	0.12
MgO	16.42	12.25	13.12	12.09	13.10
CaO	10.45	11.65	11.77	11.96	11.77
Na ₂ O	2.88	2.69	3.14	2.81	2.90
K ₂ O	1.17	0.88	0.89	0.95	1.02
Total	96.17	98.84	98.68	98.06	98.05
Si	6.661	5.993	5.930	5.888	5.847
Al ^{IV}	1.160	2.007	2.070	2.112	2.153
Ti	0.179	0.000	0.000	0.000	0.000
Total	8.000	8.000	8.000	8.000	8.000
Al ^{VI}	0.000	0.247	0.073	0.281	0.088
Ti	0.053	0.665	0.648	0.689	0.579
Cr	0.000	0.002	0.000	0.006	0.000
Fe ³⁺	0.721	0.000	0.000	0.000	0.152
Fe ²⁺	0.586	1.379	1.369	1.322	1.277
Mn	0.049	0.026	0.027	0.021	0.015
Mg	3.591	2.680	2.882	2.680	2.889
Total	5.000	5.000	5.000	5.000	5.000
Ca	1.642	1.832	1.858	1.906	1.865
Na	0.358	0.168	0.142	0.094	0.135
Total	2.000	2.000	2.000	2.000	2.000
Na	0.461	0.597	0.756	0.716	0.697
K	0.218	0.165	0.167	0.180	0.193
Total	0.679	0.762	0.923	0.896	0.890

Table 4. Selected analyses of minerals. F, Mica

	Manengouba, stage 2		Manengouba, stage 4	
#	Eb11	Eb11	KOS7	KOS7
Petrographical facies	M	M	M	M
Mineral type	phenocryst	phenocryst	microphenocrys	microcryst
SiO ₂	40.56	41.02	39.60	39.27
TiO ₂	3.92	3.90	4.99	5.74
Al ₂ O ₃	12.33	11.88	11.97	12.36
Cr ₂ O ₃	0.00	0.11	0.00	0.00
FeO	9.56	8.97	9.51	10.02
MgO	20.59	20.61	19.60	18.54
CaO	0.08	0.00	0.01	0.03
MnO	0.11	0.00	0.13	0.11
Na ₂ O	0.99	0.84	1.40	1.02
K ₂ O	9.00	9.31	8.49	8.60
Total	97.14	96.64	95.70	95.69
Si	3.152	3.196	3.128	3.107
Al ^{IV}	0.848	0.804	0.872	0.893
Total	4.000	4.000	4.000	4.000
Al ^{VI}	0.282	0.287	0.241	0.260
Ti	0.229	0.229	0.296	0.342
Fe	0.621	0.584	0.628	0.663
Mg	2.386	2.394	2.308	2.187
Mn	0.007	0.000	0.009	0.008
Total	3.525	3.493	3.482	3.459
K	0.894	0.927	0.857	0.870
Na	0.149	0.127	0.215	0.156
Total	1.044	1.054	1.072	1.026

Table 4. Selected analyses of minerals. G, Feldspars

Manengouba, stage 1

#	CT46	MA2B	MA2B	MA2B	MA2B	MA2B	ML2
Petrographical facies	alk-B	Na-Bs	Na-Bs	Na-Bs	Na-Bs	Na-Bs	H
Mineral type	phenocryst	phenocryst	phenocryst	microcryst	microcryst	xenocryst	phenocryst
SiO ₂	50.55	50.02	50.79	52.90	54.49	56.41	52.87
Al ₂ O ₃	31.66	31.97	29.79	30.11	28.51	28.25	30.19
Fe ₂ O ₃	1.05	0.98	0.82	0.93	0.53	0.43	0.33
CaO	13.02	13.02	12.16	11.39	10.48	9.63	12.32
Na ₂ O	3.71	3.55	3.98	4.52	5.22	5.69	4.33
K ₂ O	0.01	0.26	0.25	0.31	0.36	0.53	0.23
Total	100.00	99.80	97.78	100.16	99.59	100.94	100.27
Si	2.300	2.284	2.359	2.393	2.470	2.515	2.389
Al	1.698	1.720	1.631	1.605	1.523	1.485	1.608
Fe ³⁺	0.036	0.034	0.029	0.032	0.018	0.014	0.011
Ca	0.635	0.637	0.605	0.552	0.509	0.460	0.597
Na	0.327	0.314	0.359	0.396	0.459	0.492	0.379
K	0.001	0.015	0.015	0.018	0.021	0.030	0.014
Total	4.997	5.004	4.998	4.996	4.999	4.996	4.998
% Ab	34.00	32.52	36.64	41.02	46.41	50.08	38.34
% An	65.94	65.91	61.86	57.12	51.48	46.84	60.29
% Or	0.06	1.57	1.49	1.86	2.11	3.08	1.37

Table 5. Chemical analyses of the rocks

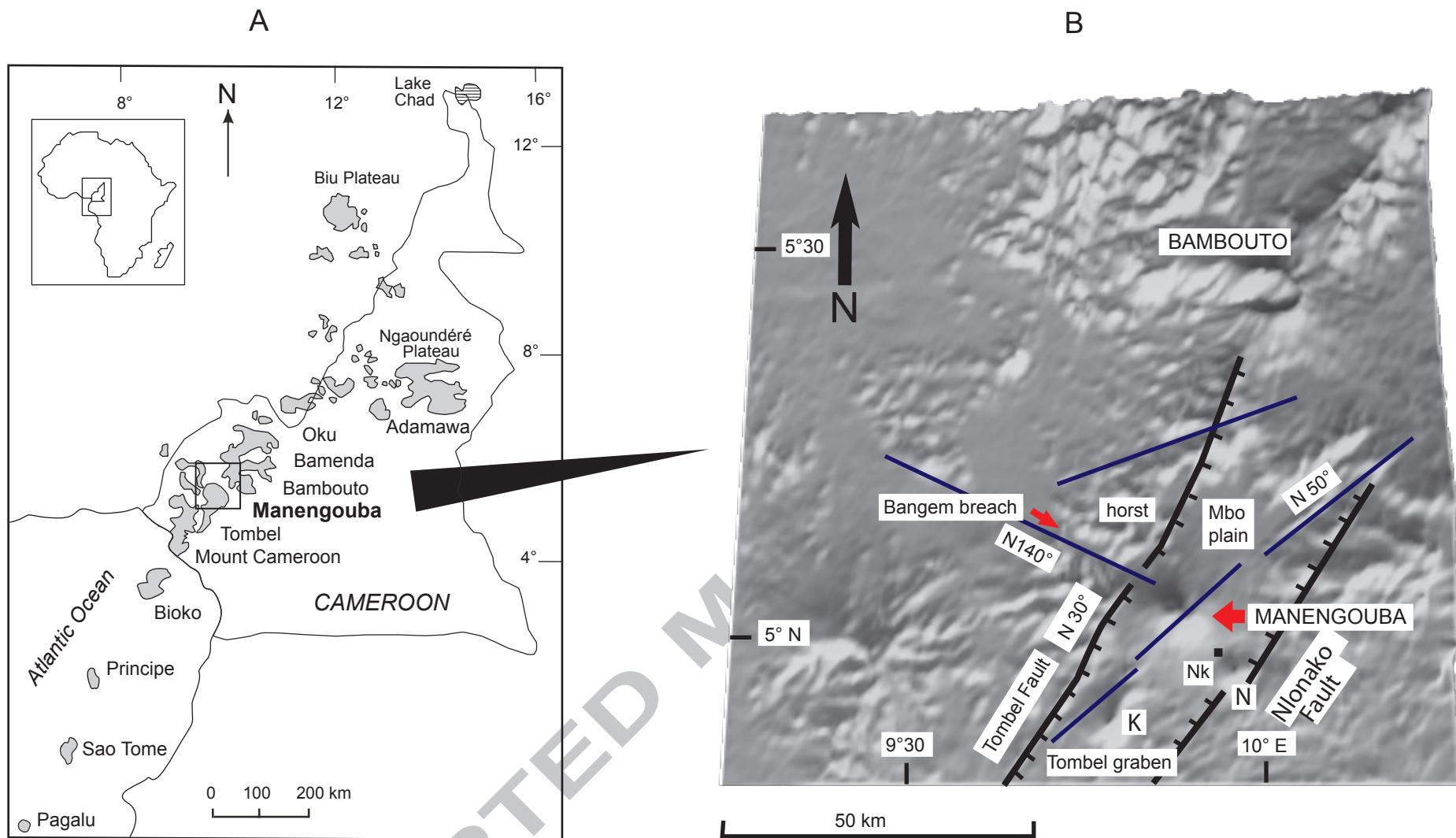
Manengouba, stage 1

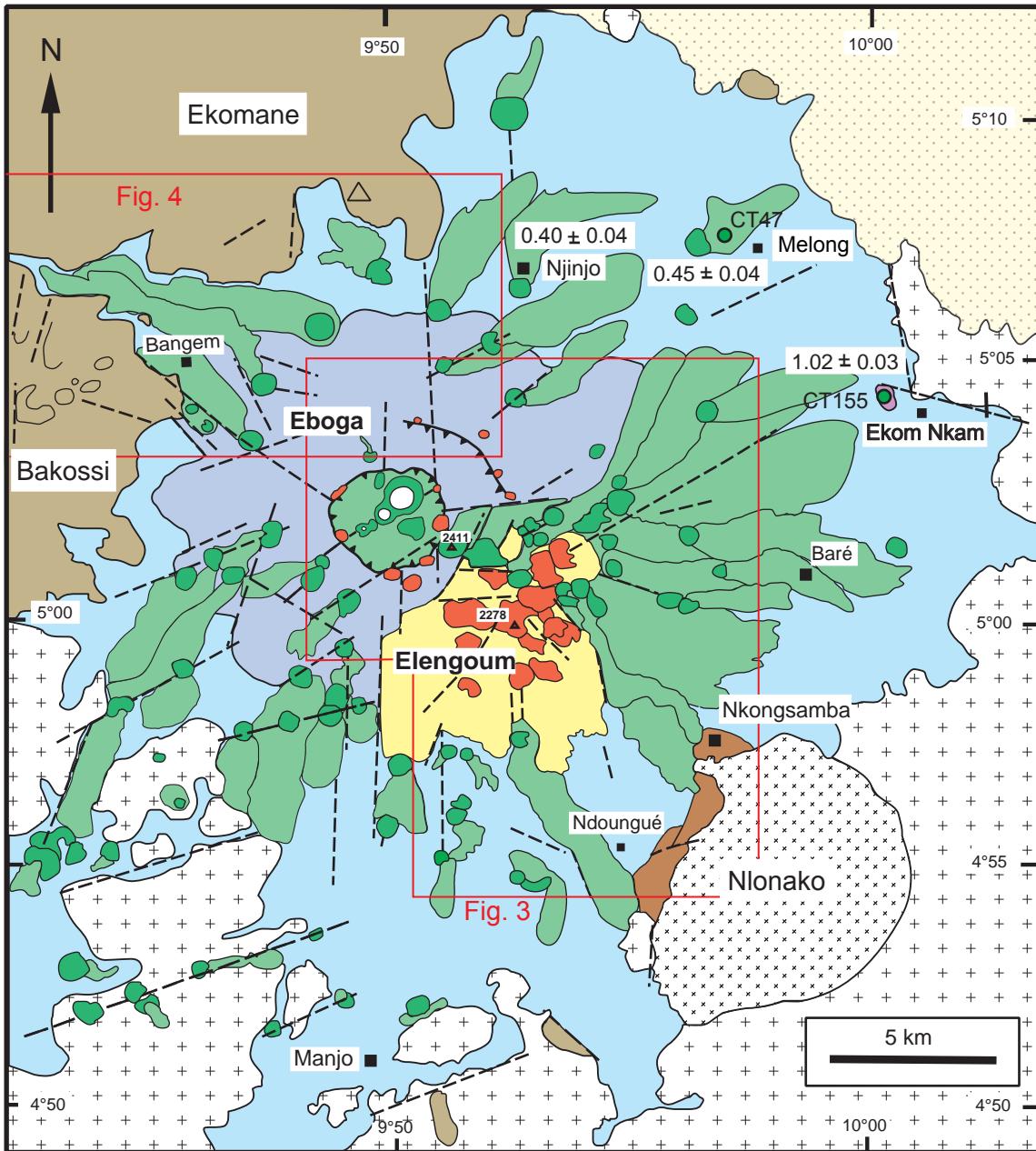
Location	Ekon-Nkam fall	Mantem	N Manjo Mahongué river	E Manjo Moo river	Enyandong Mbe river
#	KO1	CT46	MA2B	ML2	DN1
Setting type	flow	flow	flow	flow	flow
Petrographical facies	Ank	alk B	Na-Bs	H	Na-H
SiO ₂	43.38	46.58	45.83	47.47	46.62
TiO ₂	2.61	2.47	2.71	2.67	2.75
Al ₂ O ₃	13.10	15.14	15.03	16.17	17.13
Fe ₂ O ₃ t	12.79	12.72	11.89	11.38	10.98
MnO	0.17	0.17	0.17	0.18	0.18
MgO	11.04	8.51	6.94	5.55	3.85
CaO	10.67	8.19	9.94	9.15	9.30
Na ₂ O	2.66	2.67	3.24	3.83	4.47
K ₂ O	1.29	1.43	1.61	1.54	1.61
P ₂ O ₅	0.61	0.62	0.65	0.77	0.88
LOI	1.40	1.47	1.64	0.91	1.87
TOTAL	99.72	99.97	99.65	99.62	99.64
DI	24.37	31.88	33.80	39.33	42.20
V	251	192.2	213	183	192
Cr	399	318.7	236	128	39.0
Co	49.3	45.02	36.3	29.4	24.0
Ni	241.0	222.5	113.0	73.0	19.0
Cu	68.93	61.06	46.95	40.89	23.37
Ga	20.32	23.84	23.4	24.33	23.1
Rb	35.00	32.91	52.00	36.00	35.00
Sr	661.0	564.5	790.0	1027.0	808.0
Y	23.30	48.29	26.70	30.10	31.80
Zr	201.0	314.6	243.0	282.0	244.0
Nb	57.82	58.37	68.43	75.02	58.9
Ba	492.0	539.6	533.0	637.0	504.0
Hf	4.00	6.84	6.03	6.23	5.53
Ta	4.04	4.32	4.95	5.22	4.35
Pb	2.17	2.79	3.89	3.02	2.75
Th	4.60	4.84	6.77	6.87	4.40
U	1.30	1.28	2.27	1.70	1.18
La	40.05	58.87	61.17	68.12	49.28
Ce	77.90	92.85	118.00	135.00	103.00

Table 6 Isotopic data

Location	Sample	Rock type	Age (Ma)	Rb	Sr	$^{87}\text{Sr}/^{86}\text{Sr}$	Sm	Nd	$^{143}\text{Nd}/^{144}\text{Nd}$	ϵ_{Nd}	U	Th	Pb	$^{206}\text{Pb}/^{204}\text{Pb}$	$^{207}\text{Pb}/^{204}\text{Pb}$	$^{208}\text{Pb}/^{204}\text{Pb}$
Pre-Manengouba																
NW borders																
Essom	CT-107	T	13.56	96.0	116	0.706216 ± 5	14.18	81.18	0.512558 ± 11	-1.35	3.22	13.2	13.6	18.45	15.59	38.85
Bakossi	CT-103	Ph	7.55	254	33.8	0.707574 ± 6	10.81	61.67	0.512756 ± 5	2.49						
E-volc. substratum																
NE-Nlonako	KBT 5	H	9.27	37	900	0.703326 ± 7	11.1	56.9	0.512910 ± 12	5.44						
Manengouba																
Ekom Caldera	CT-155	Rh	1.02	200	6.2	0.708554 ± 5	4.04	17.0	0.512764 ± 19	2.47	1.8	31.4	3.77	18.79	15.60	39.04
Eboga SE-floor	KEB 19	H	0.28	50.9	616	0.703114 ± 7	9.28	46.3	0.512924 ± 12	5.58						
Eboga NW-floor	KEB 33	H	0.14	36.0	524	0.703045 ± 7	7.42	35.0	0.512923 ± 16	5.56						
Flank activity																
Mboassoum	CT-108	H	0.45	30.9	513	0.703055 ± 7	8.06	37.0	0.512948 ± 10	6.05	1.3	4.86	2.15	19.75	15.63	39.45
W-Bangen	CT-105	T-P	0.21	144	417	0.703042 ± 9	10.8	61.7	0.512869 ± 22	4.62	6.38	23.0	8.12	19.78	15.63	39.48
Ekoh	CT-55	Bs	0.11	43.9	957	0.703041 ± 6	10.4	55.4	0.512933 ± 9	5.76						
S-Mbouroukou	KME 2a	H	0.10	32.5	746	0.703083 ± 6	9.33	45.89	0.512917 ± 16	5.44						

Fig. 1





MANENGOUBA Volcanic System

- | | | | |
|---|--|--|--|
| | 1 - Early Manengouba shield volcano (1.55 - 0.94 Ma) | | Pre-Manengouba lava flows (9 Ma) |
| | 2 - Eboga stratovolcano hawaiite - mugearite - benmoreite flows | | North-western trachyte and phonolite of the Bakossi - Ekomane shield (13.6 - 7.4 Ma) and of limited southern sites |
| | 3 - Elengoum Extrusive Complex benmoreite and trachyte extrusions (0.9 - 0.7 Ma) | | Eocene syenite intrusion |
| | 4 - Flank volcanoes, cones and flows (0.5 - 0.1 Ma) | | Neoproterozoic granite basement |
| Unrelated lavas | | | Quaternary sediments |
| | rhyolite of Ekom (1.02 Ma) | | Fault and fracture |
| | | | Caldera |

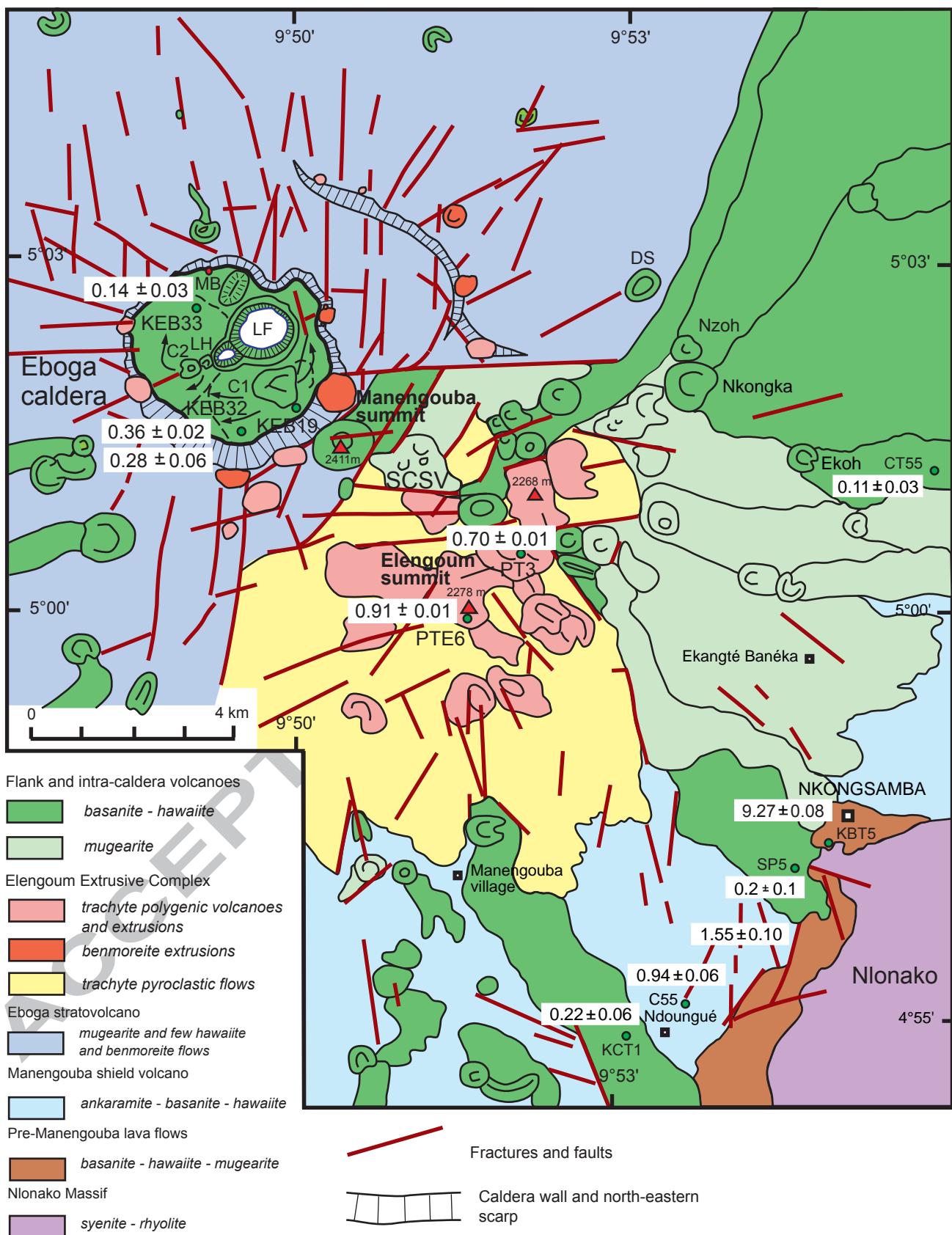
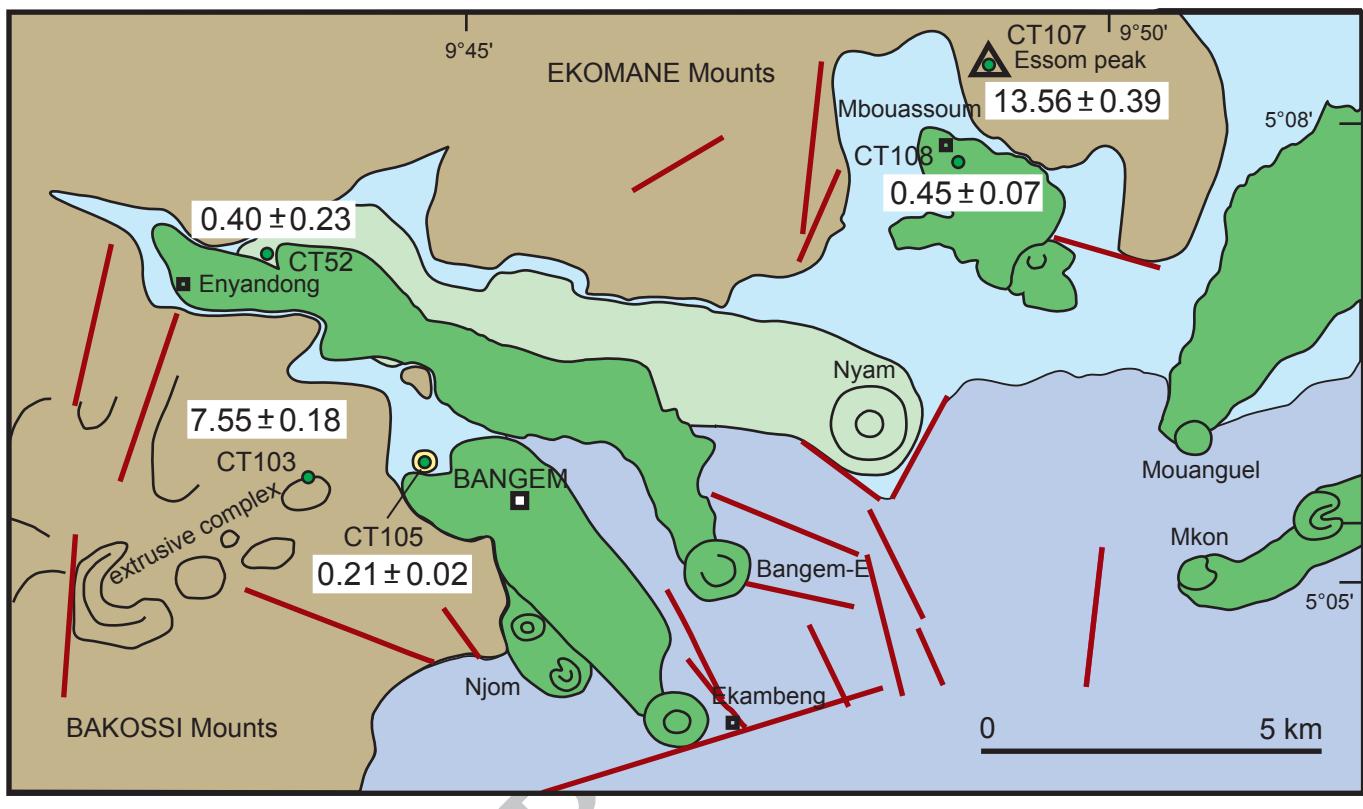


Fig. 4



ACCEPTED MANUSCRIPT

Flank volcanoes

- [Green box] basanite - hawaiite
- [Light green box] mugearite
- [Yellow box] trachy-phonolite
- [Blue box] hawaiite - mugearite - benmoreite

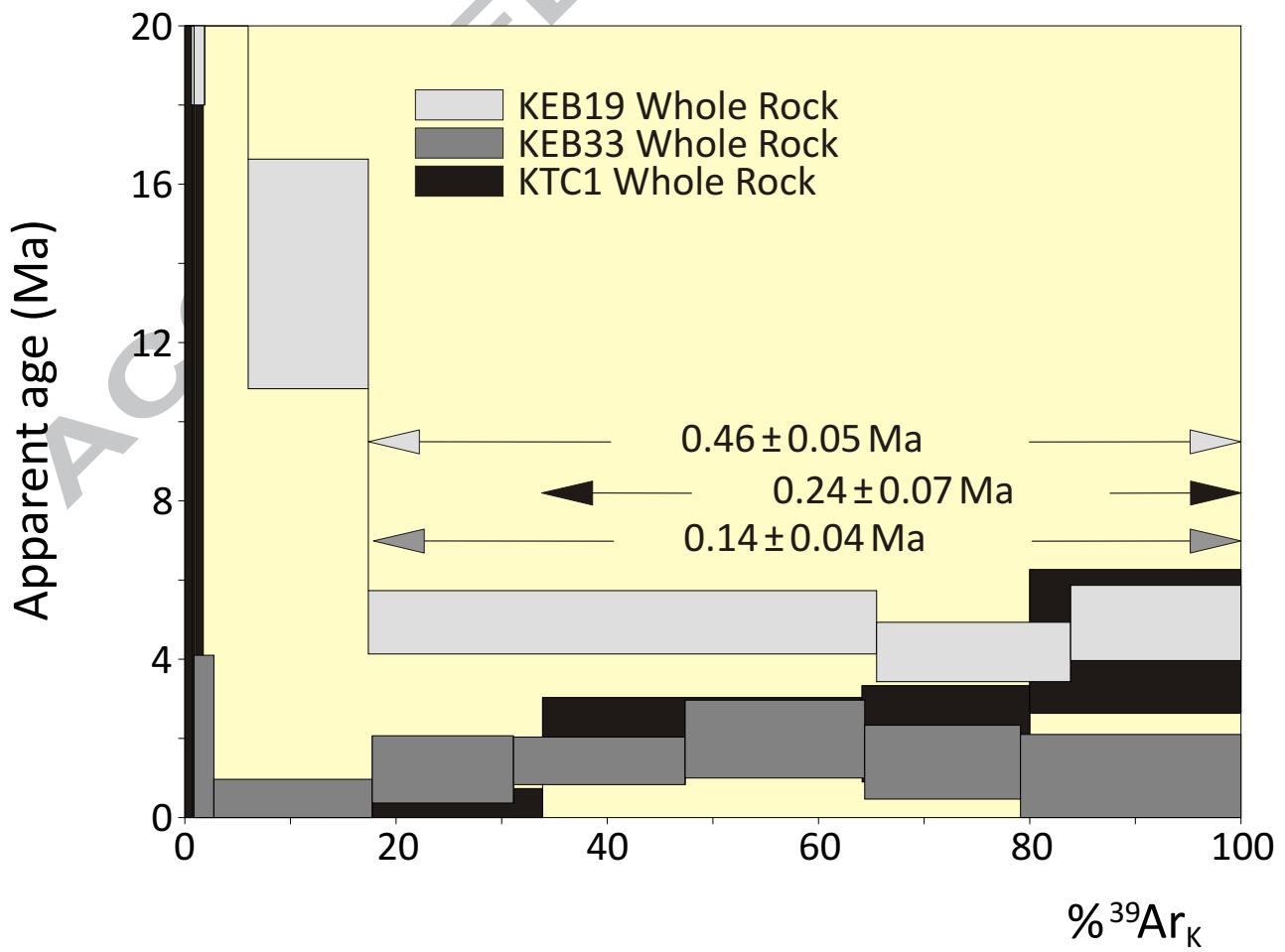
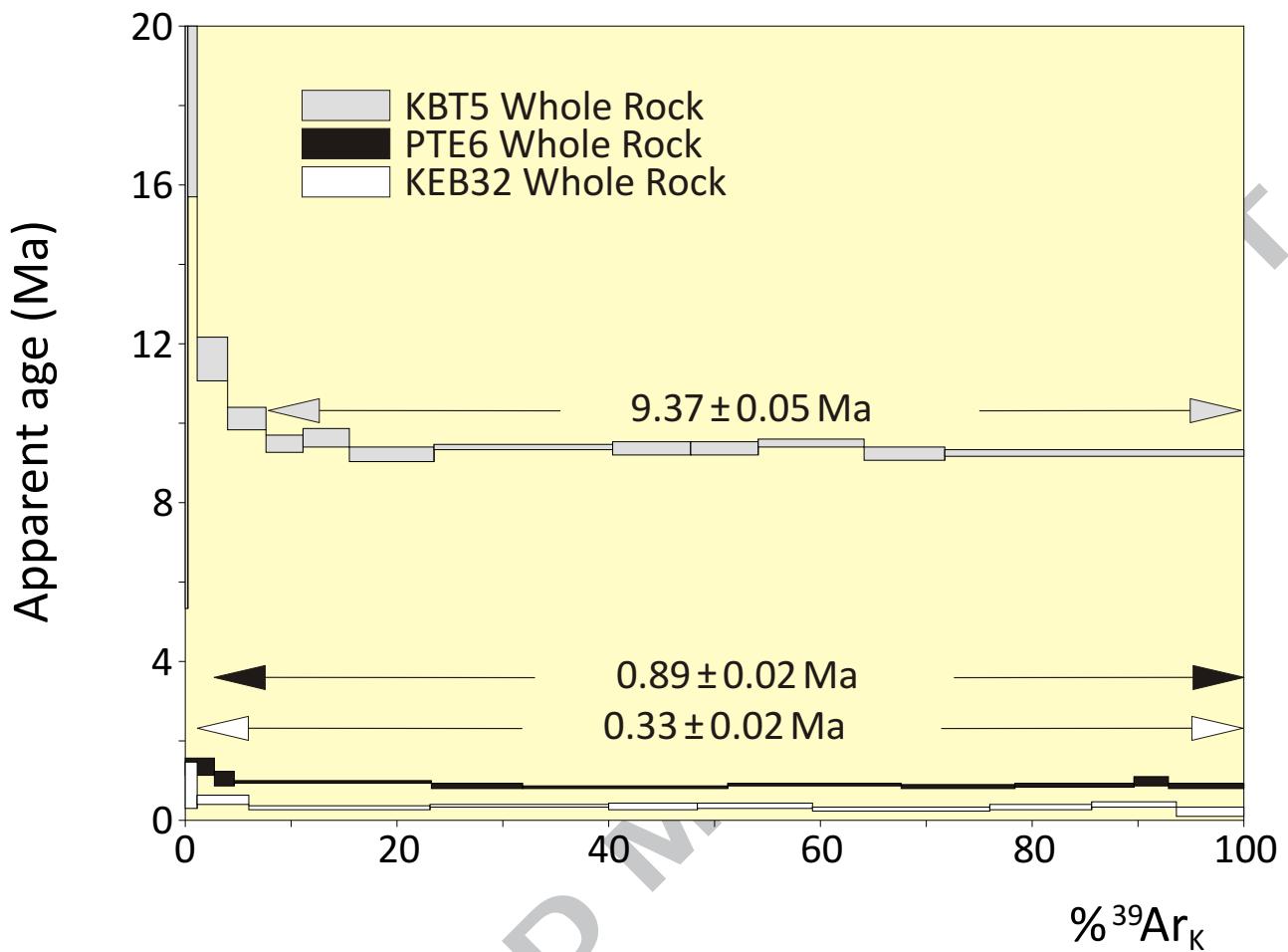
Eboga stratovolcano

Manengouba shield lava flows

- [Light blue box] basanite

Pre-Manengouba volcanic rocks

- [Brown box] trachyte - phonolite



St 1 - Manengouba shield

St 2 - Eboga stratovolcano

St 3a - Elengoum acidic extrusions and

Eboga caldera collapse

St 3b - Acidic extrusions and caldera infilling

End of the first magmatic activity

St 4 - Renewal of the activity inside the caldera
and on the flanks

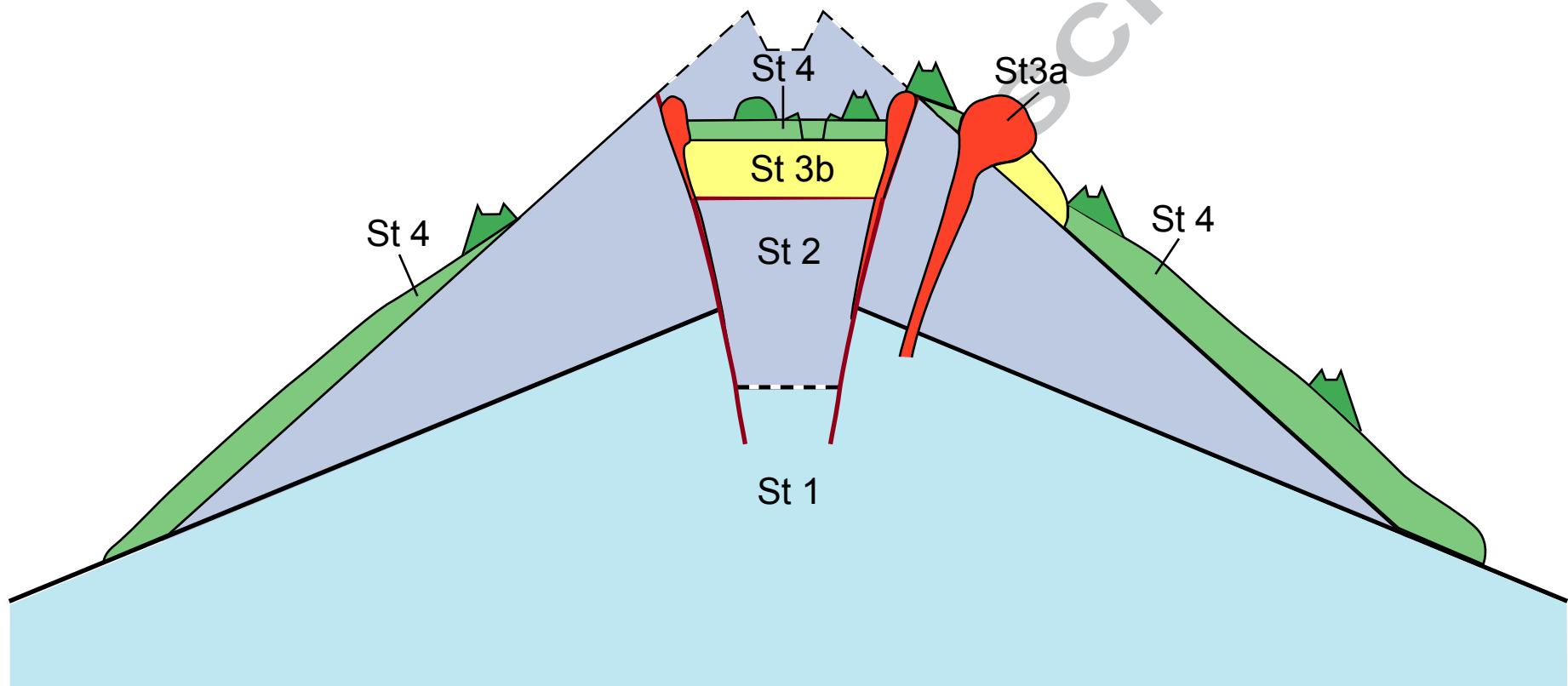
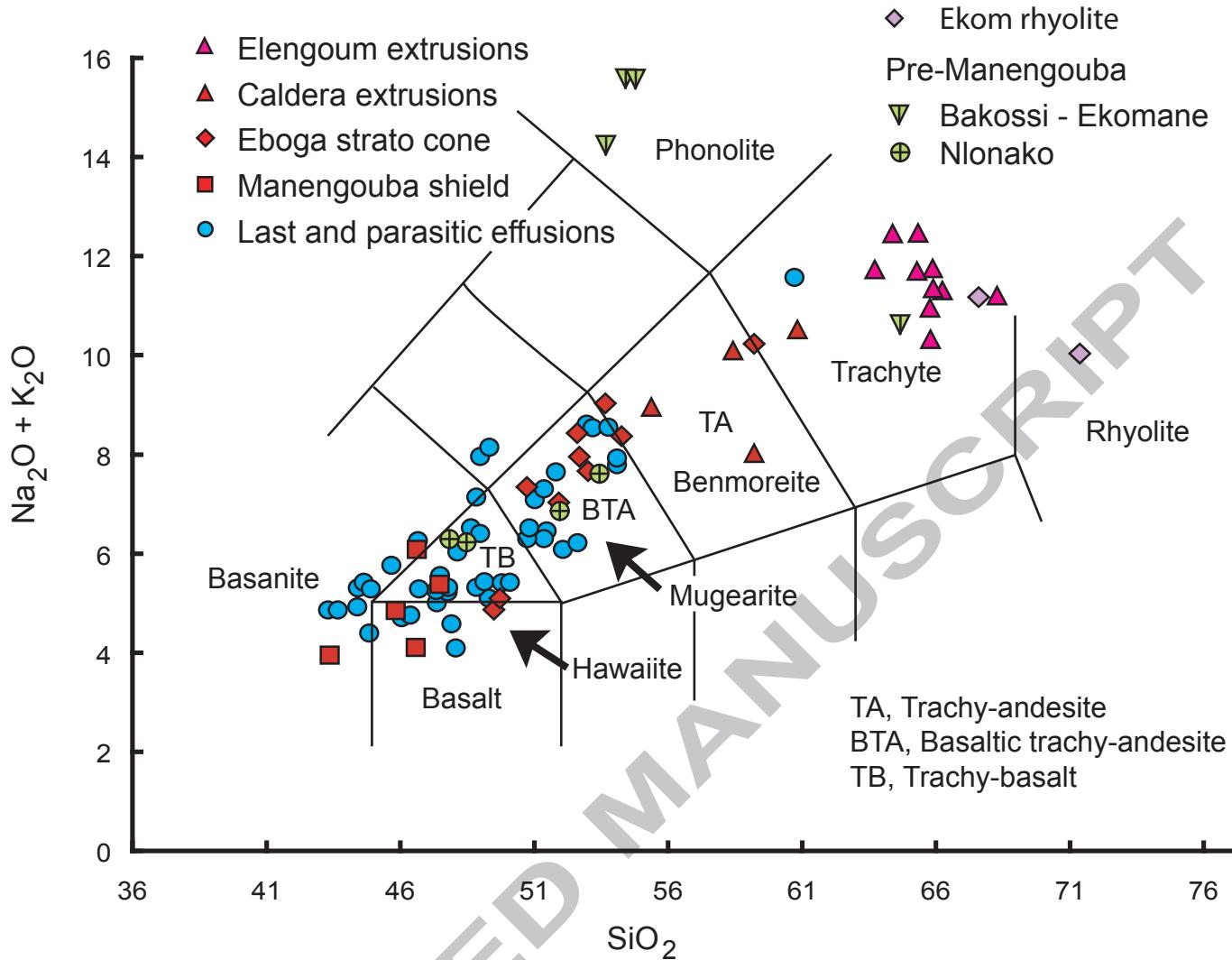


Fig. 7

ACCEPTED MANUSCRIPT

A



B

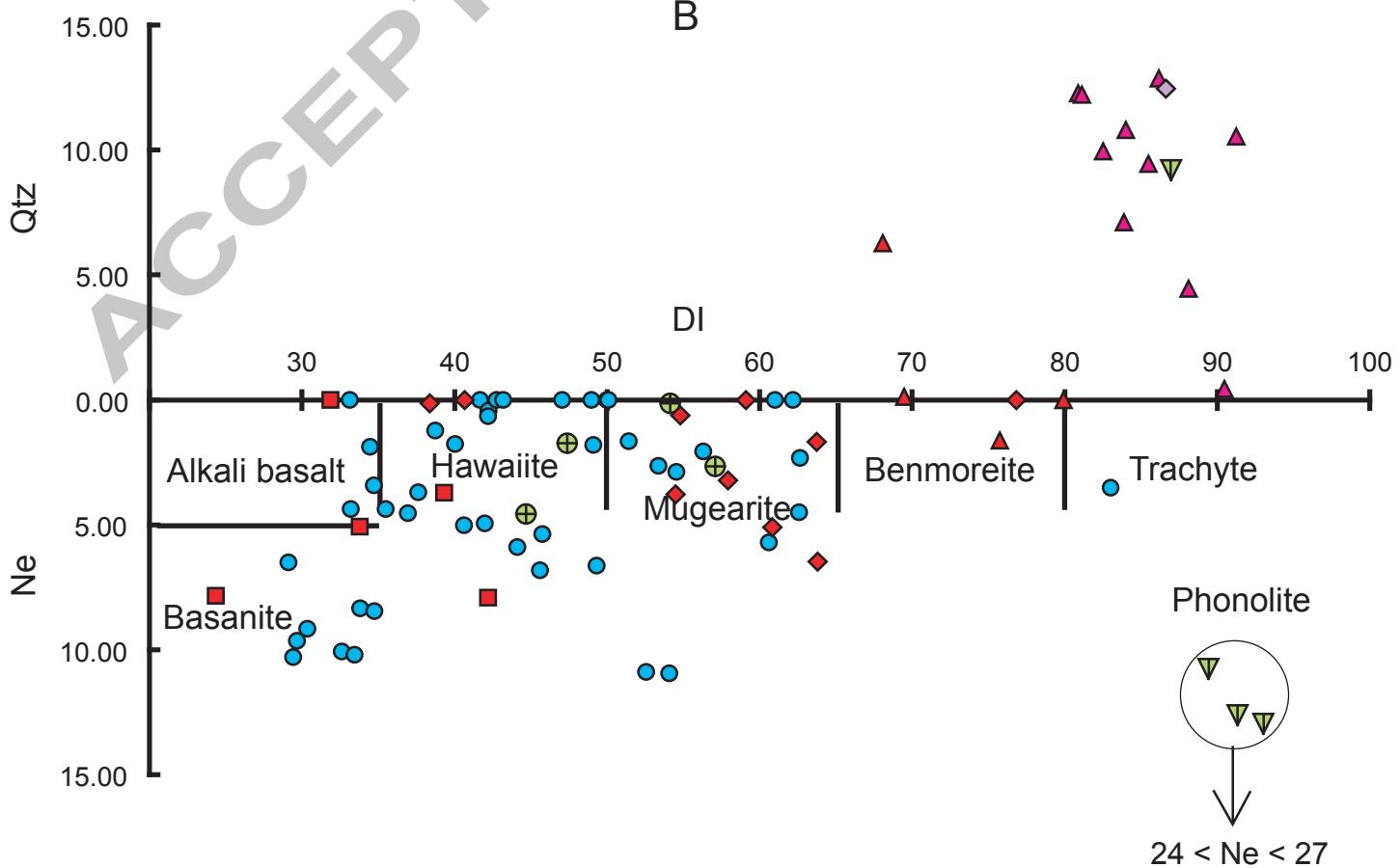


Fig. 8

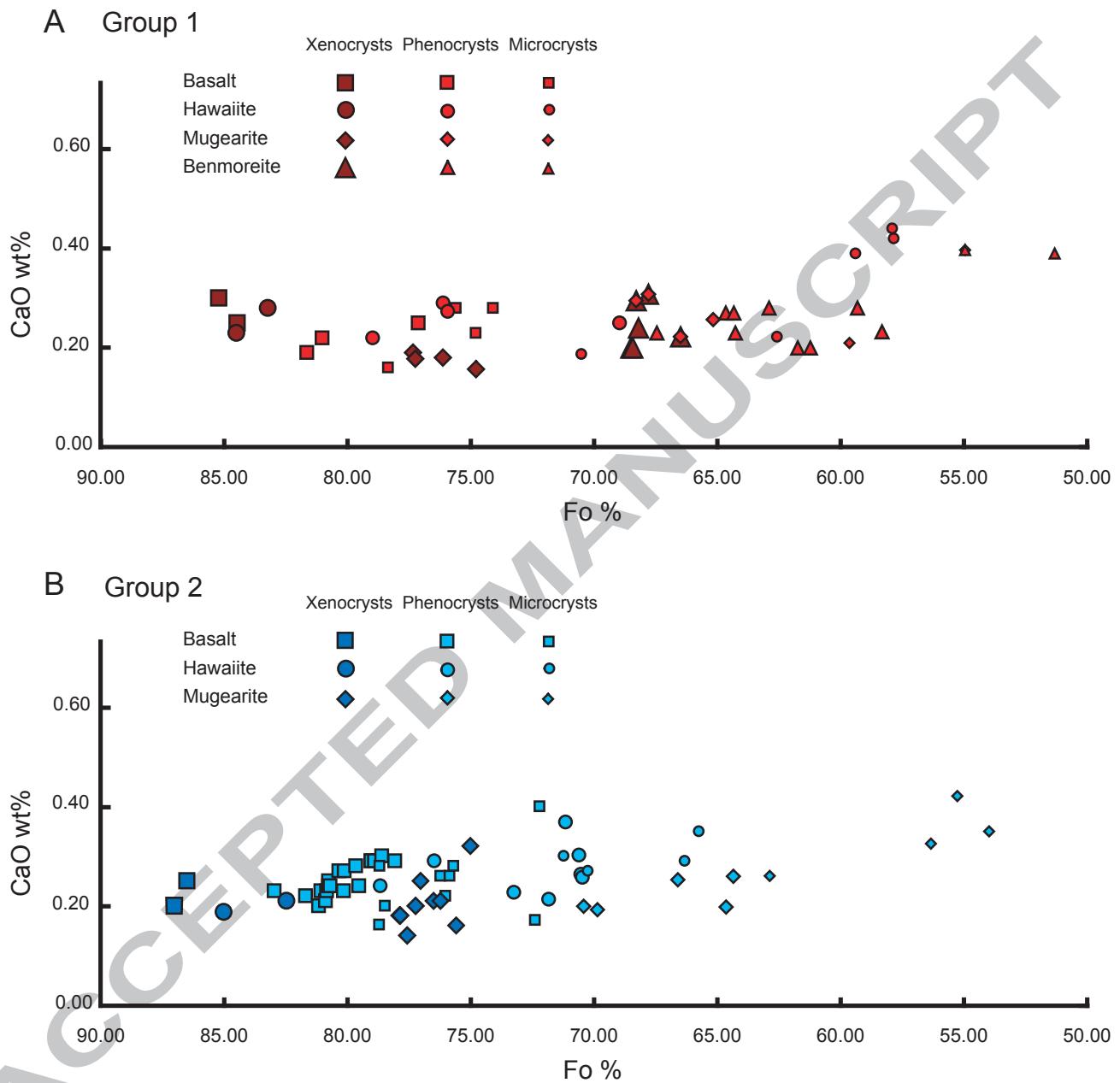


Fig. 9

ACCEPTED MANUSCRIPT

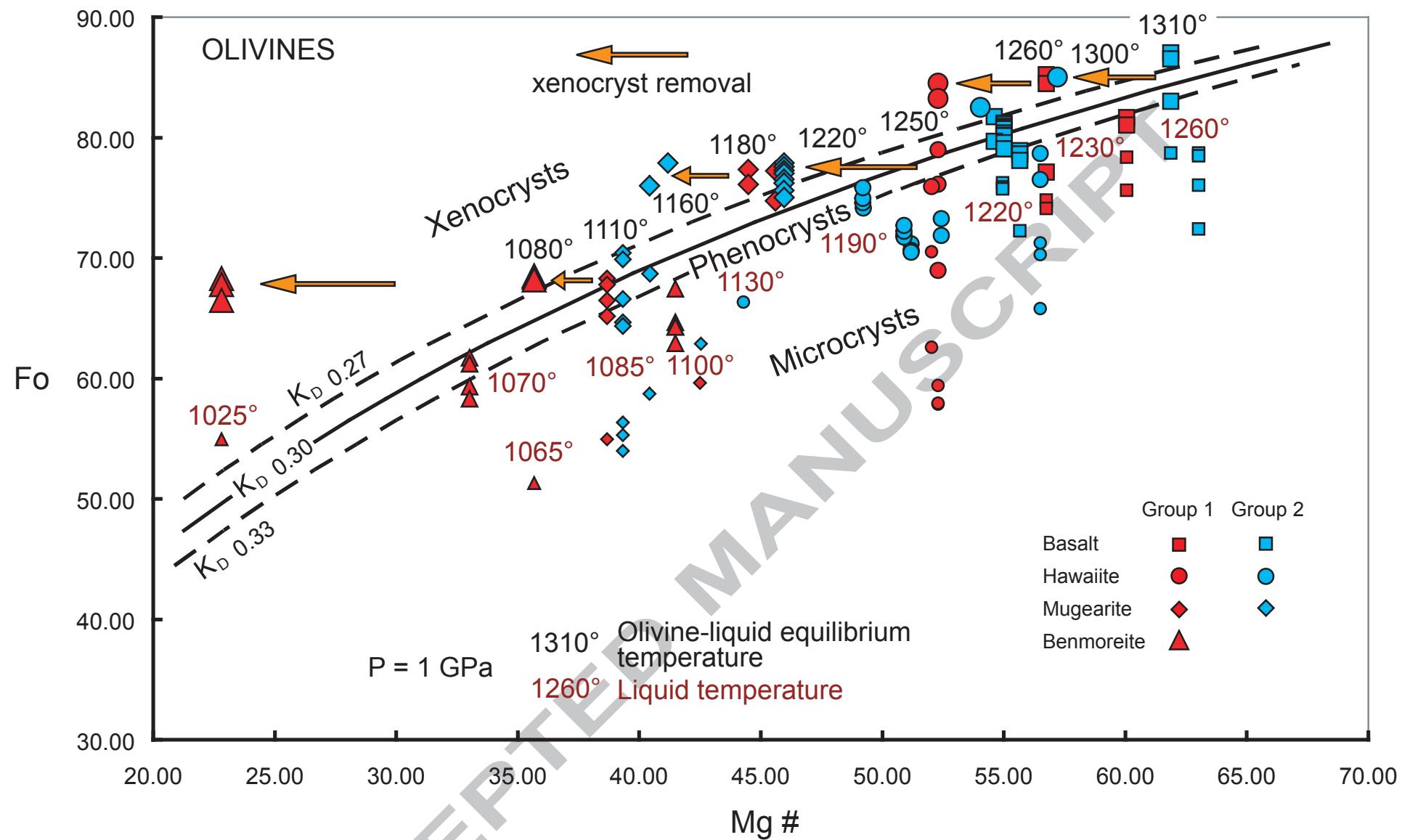


Fig. 10

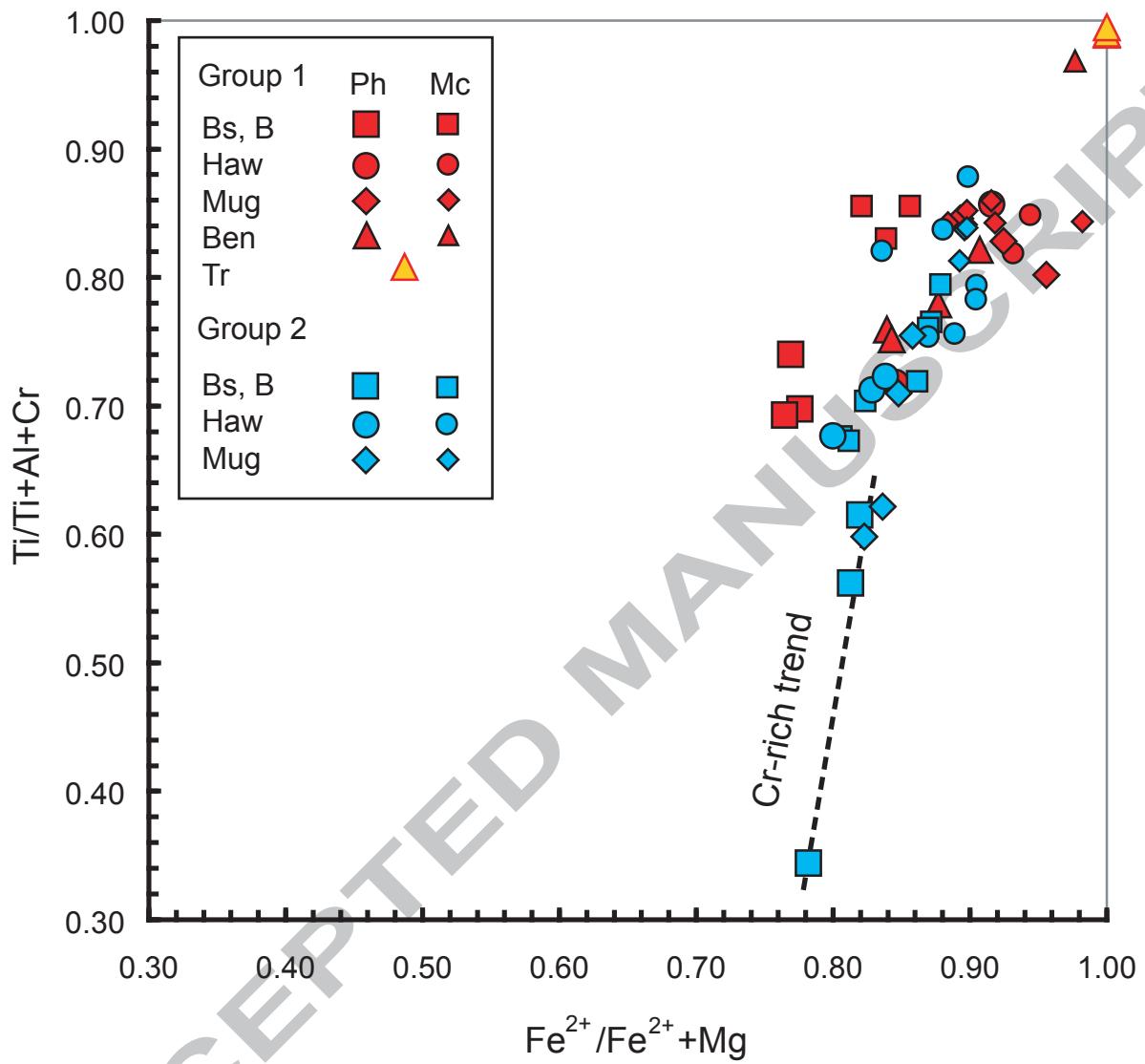


Fig. 11

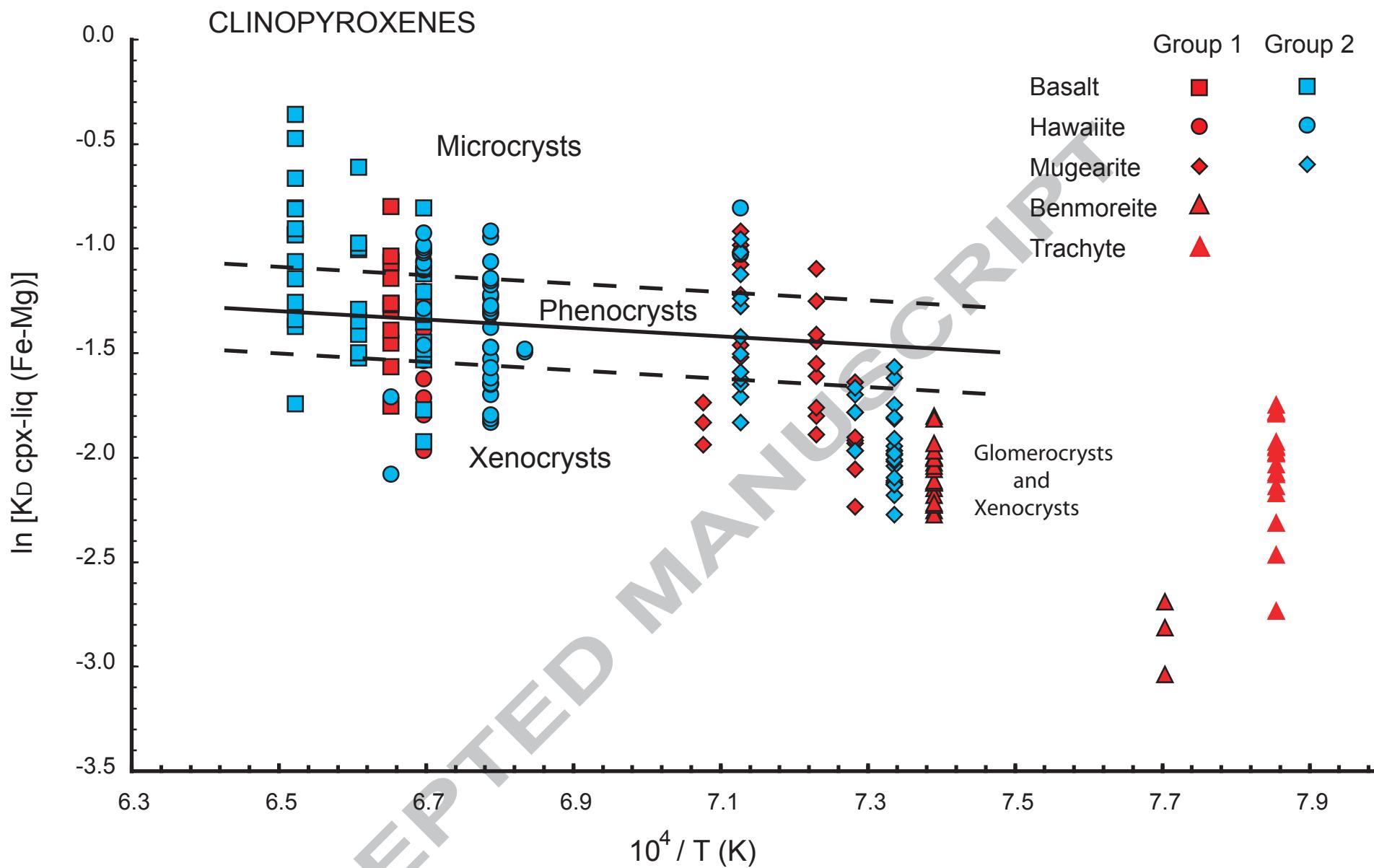
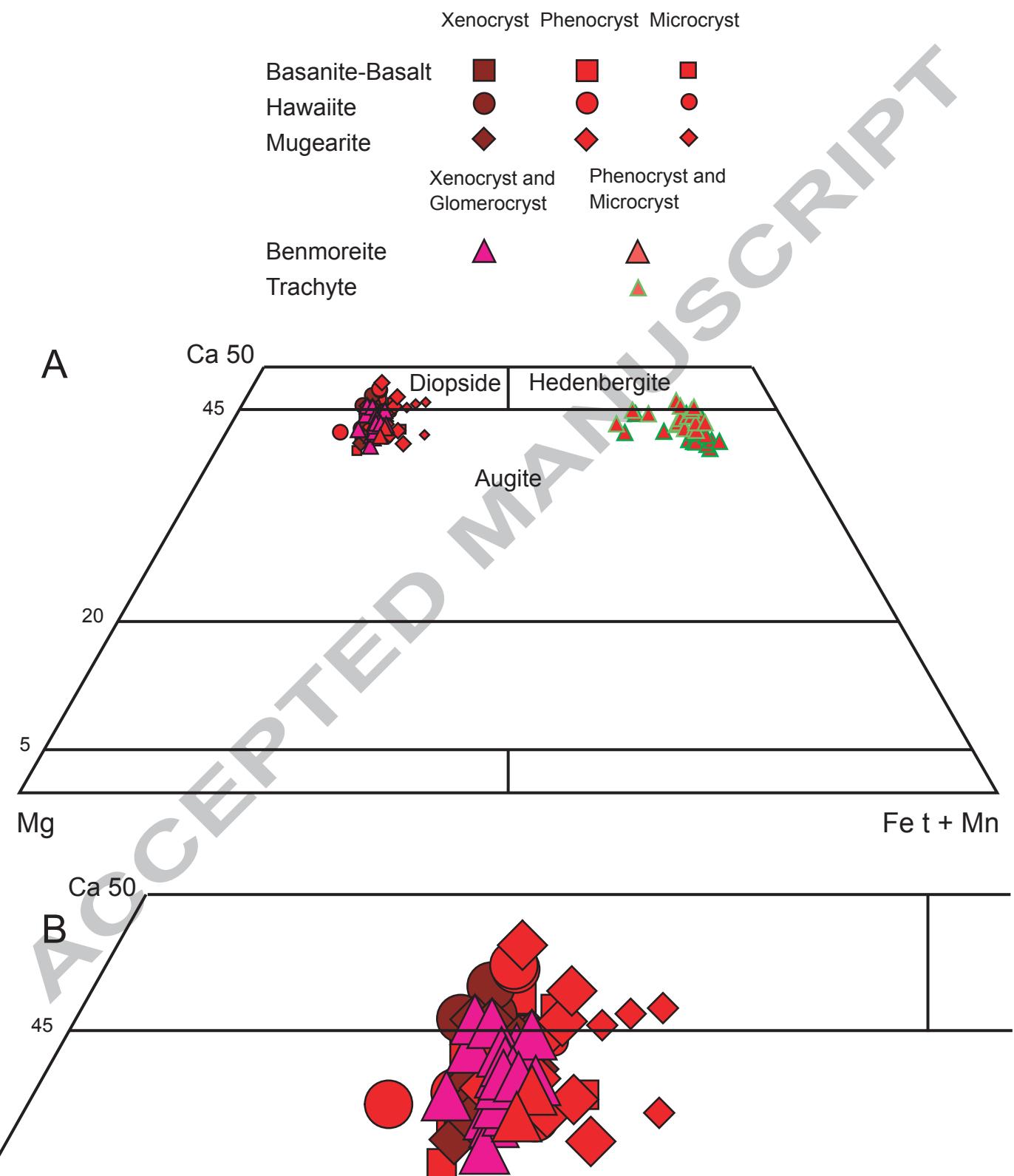


Fig. 12

PYROXENES



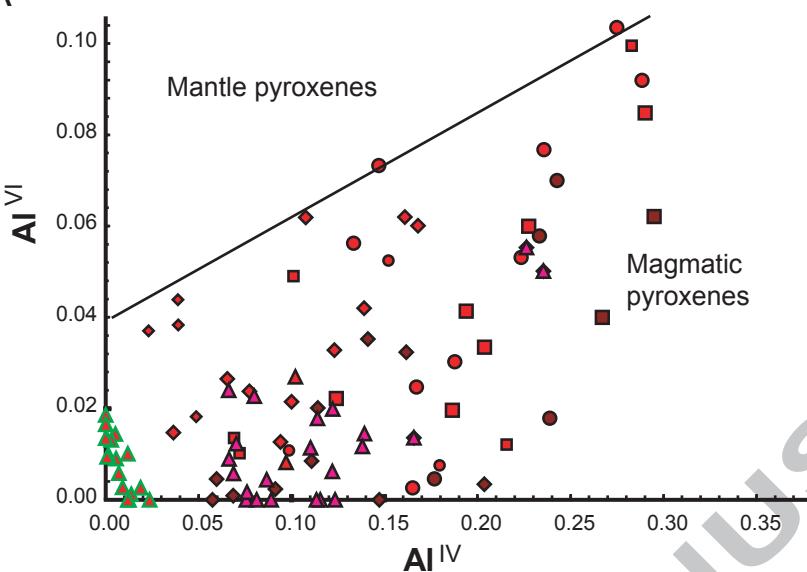
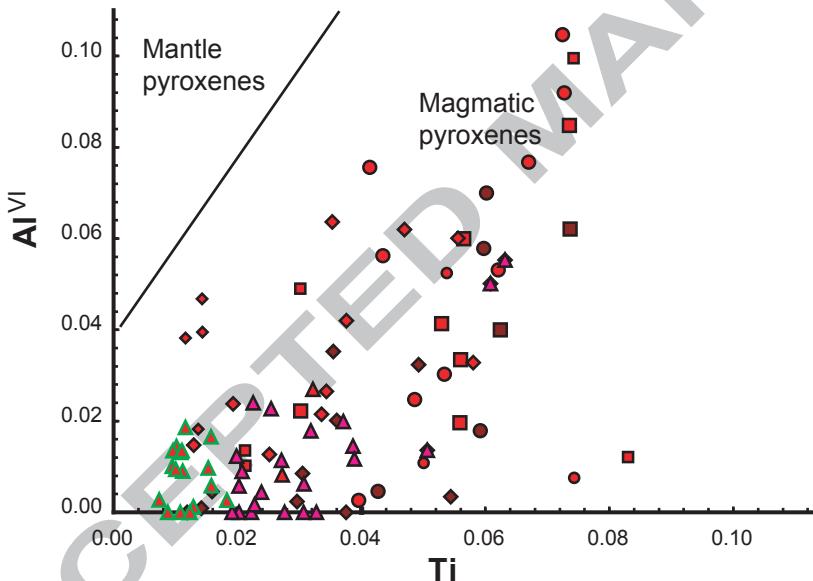
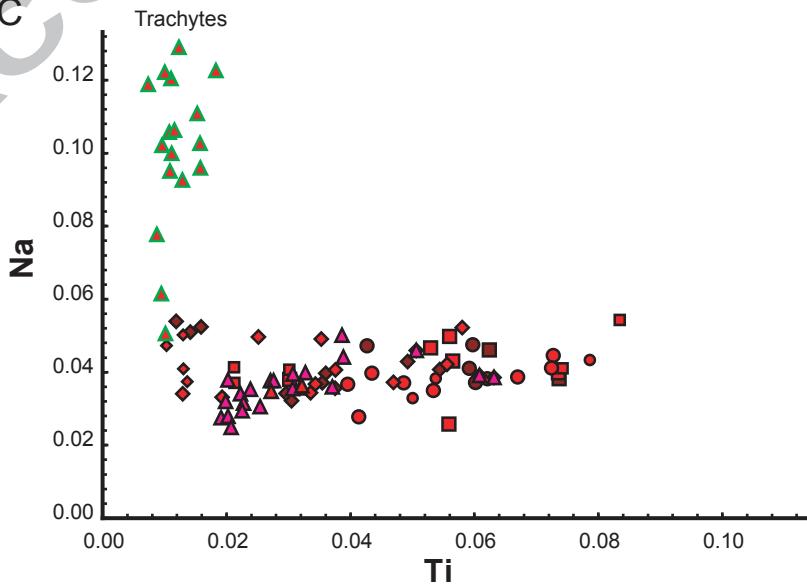
A**B****C**

Fig. 14

PYROXENES

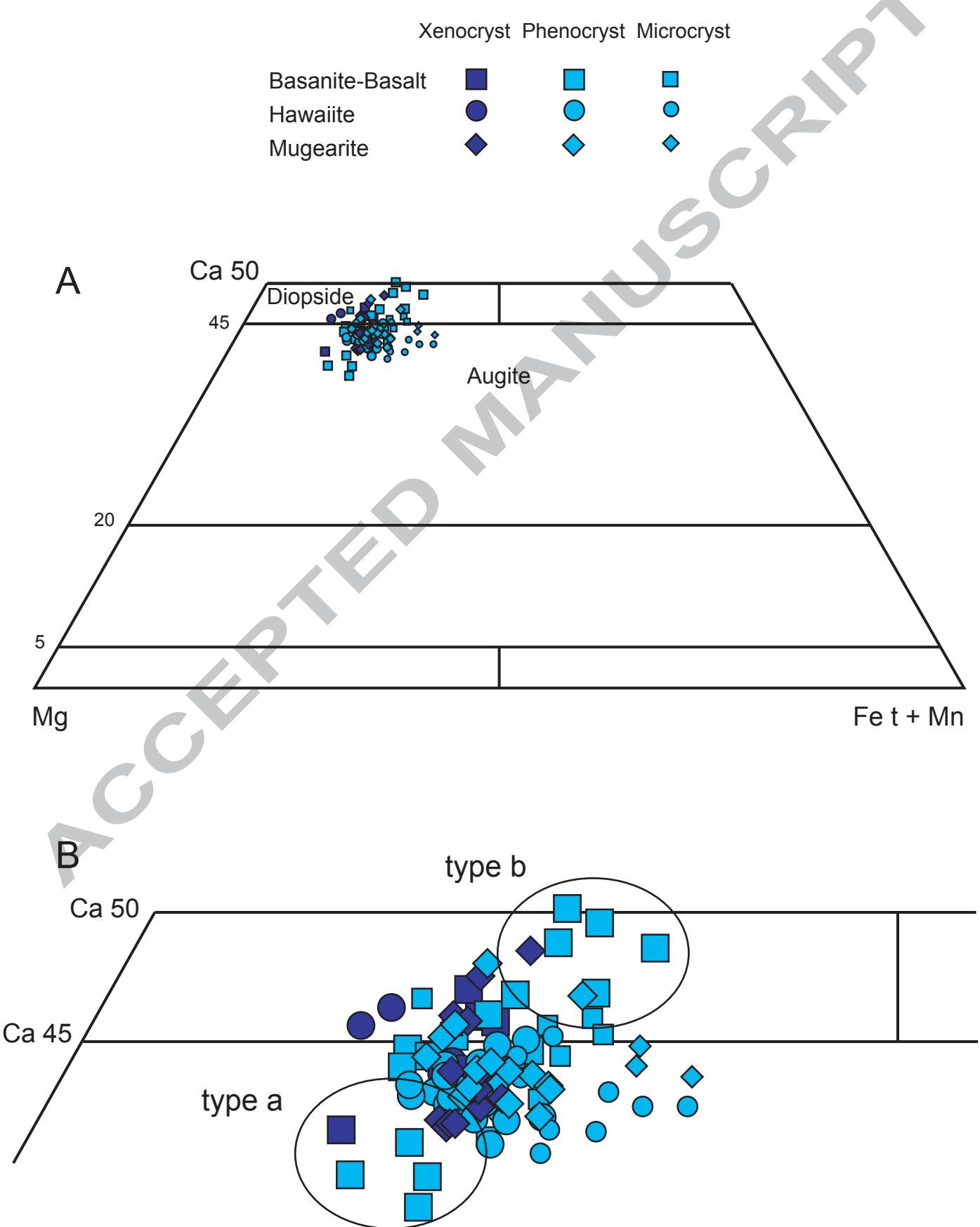
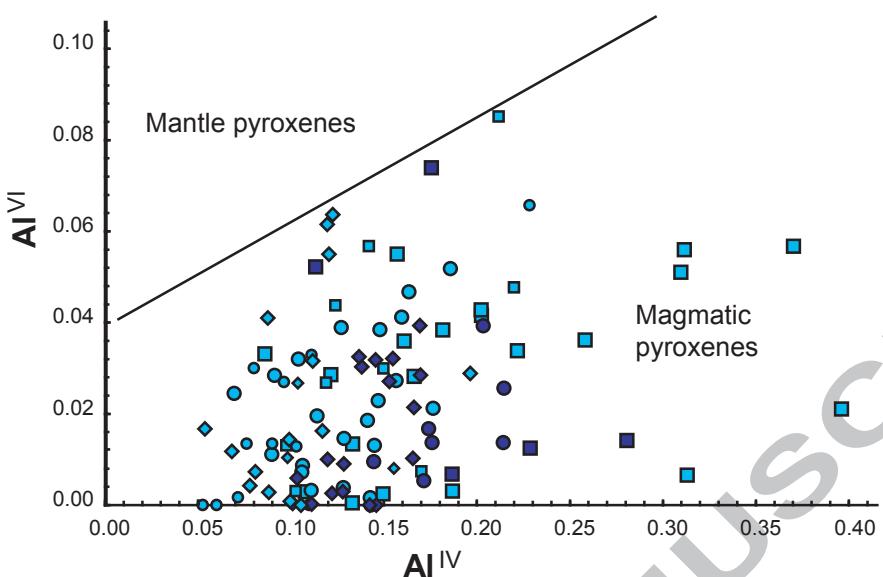


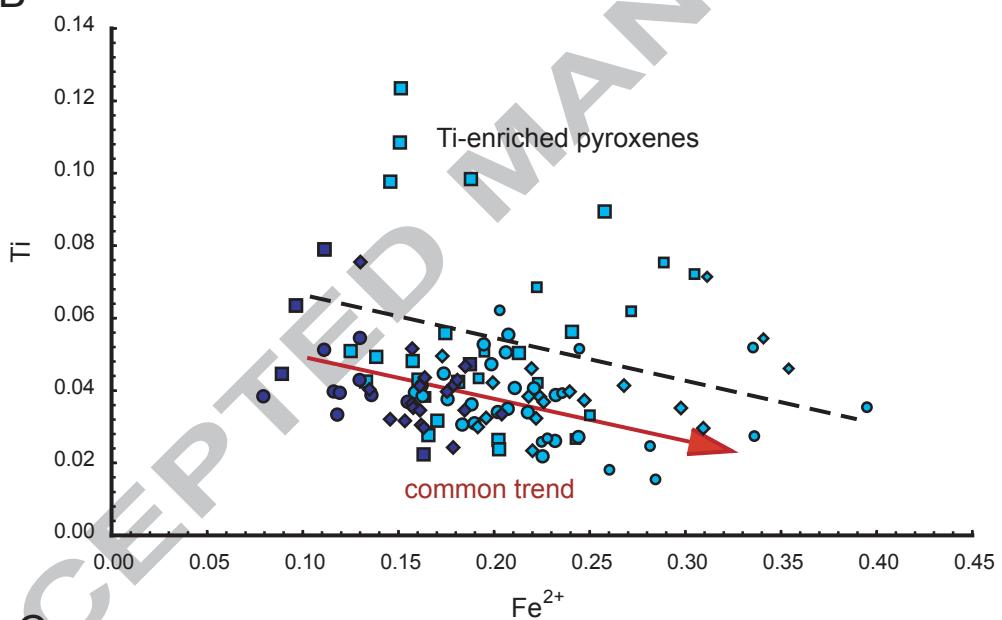
Fig. 15

ACCEPTED MANUSCRIPT

A



B



C

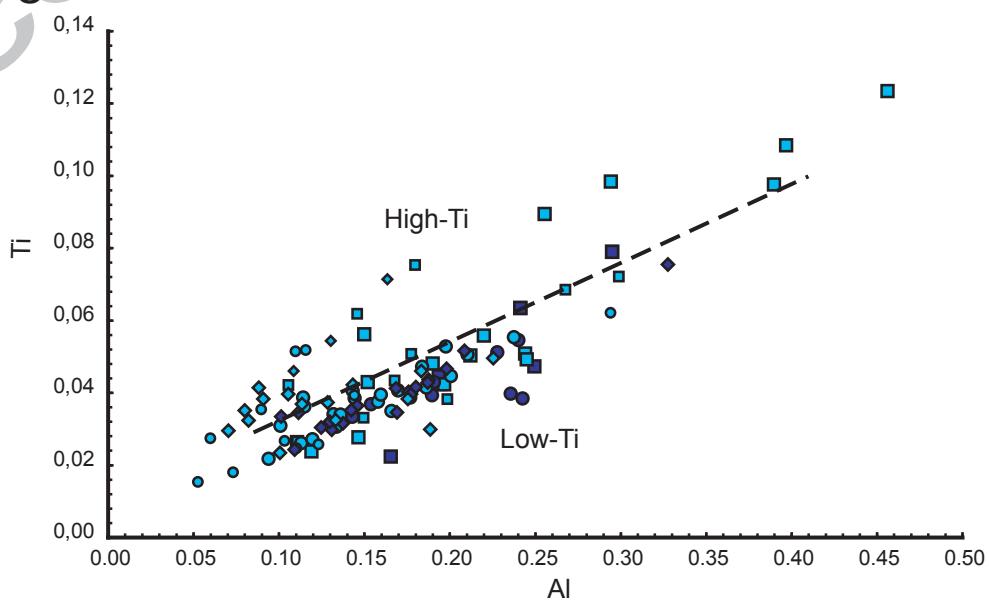
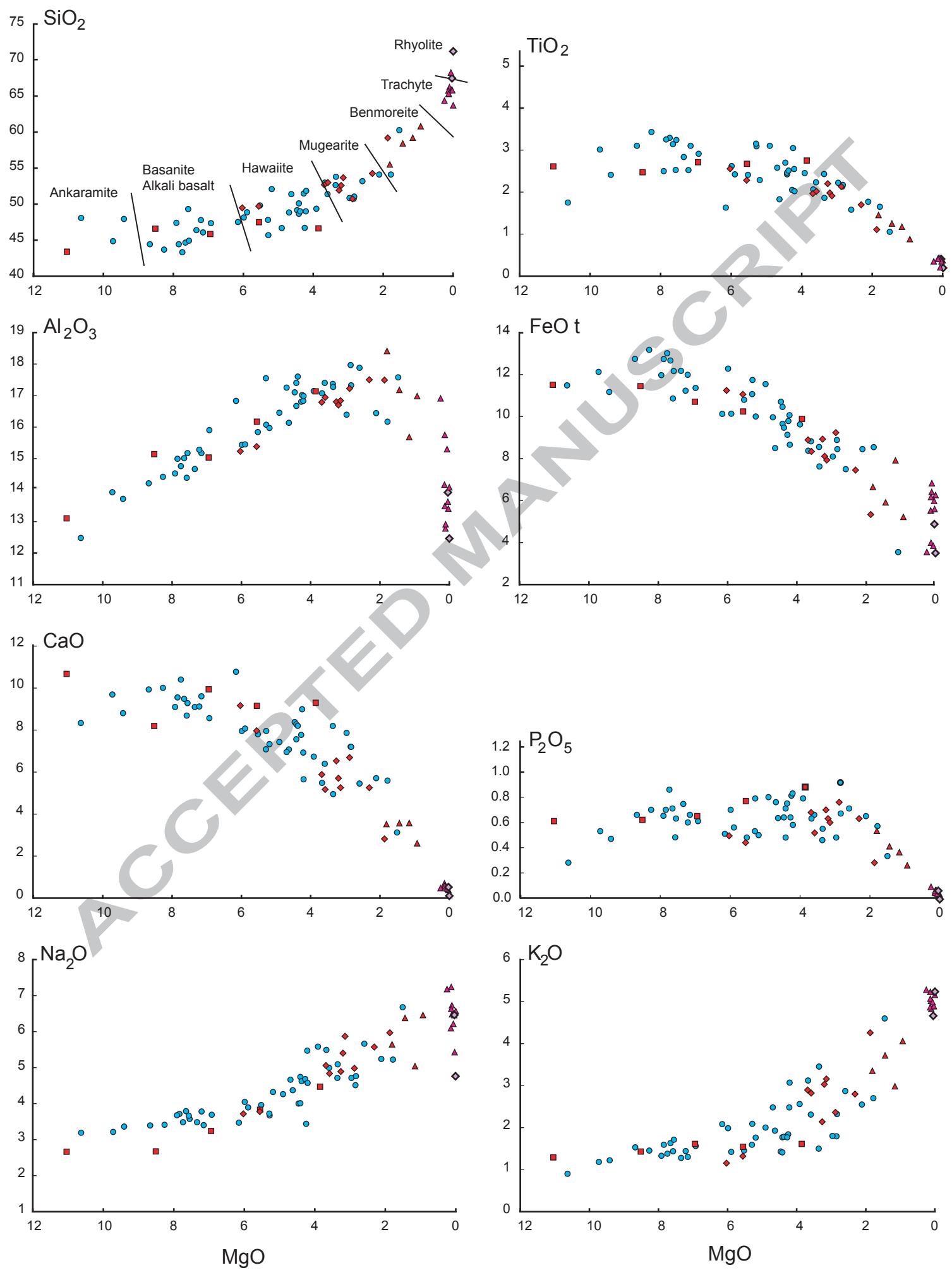
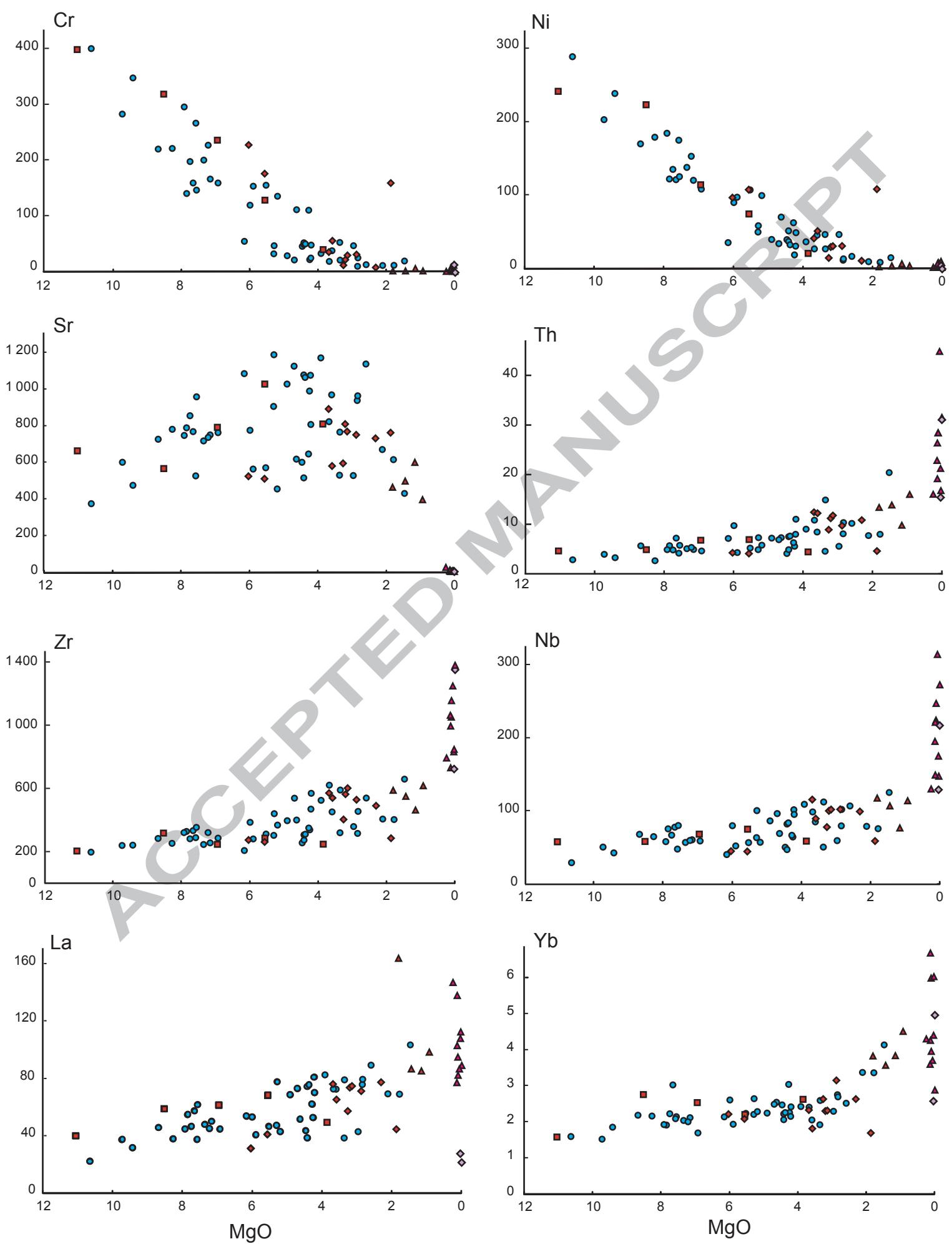
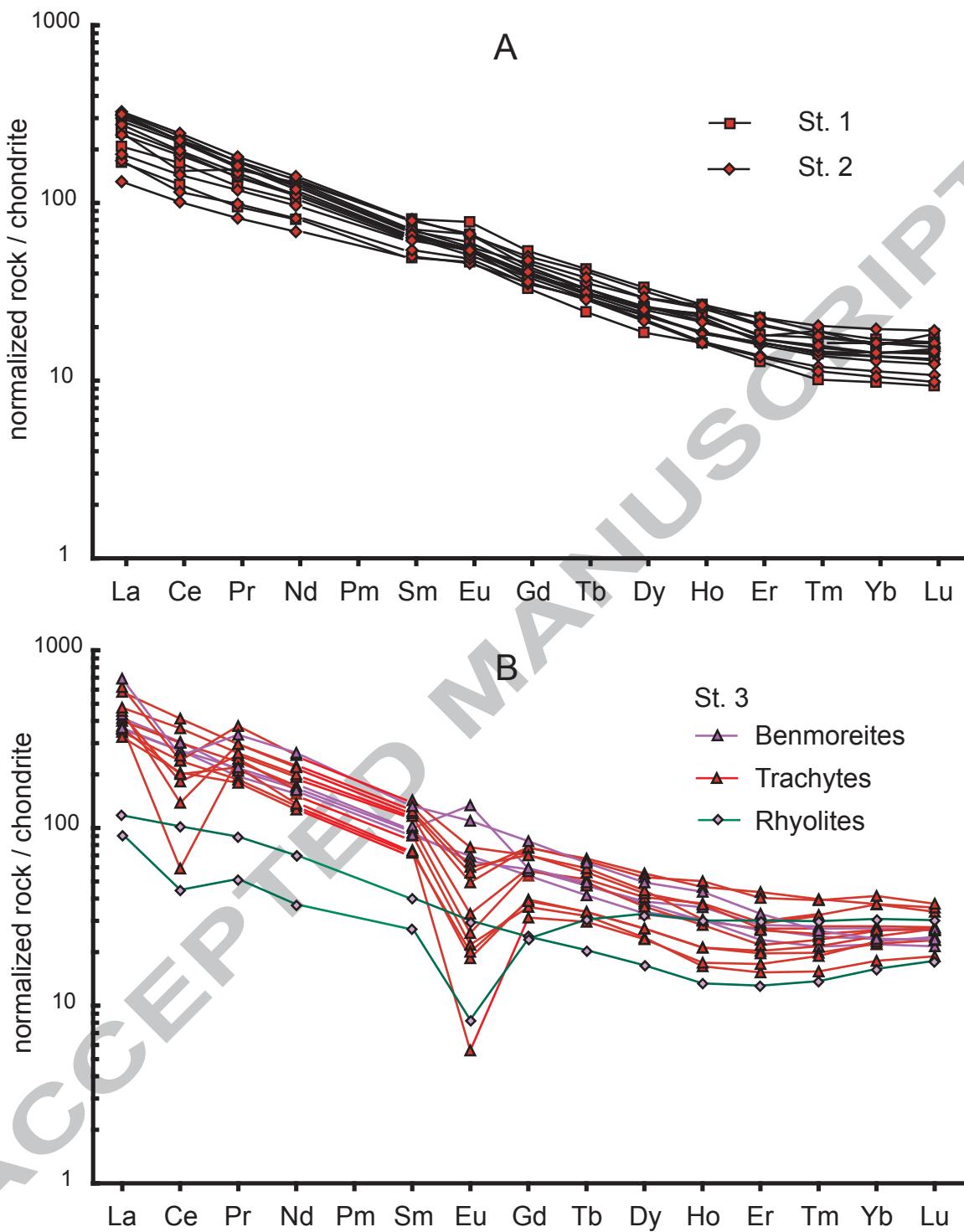


Fig. 16A

ACCEPTED MANUSCRIPT







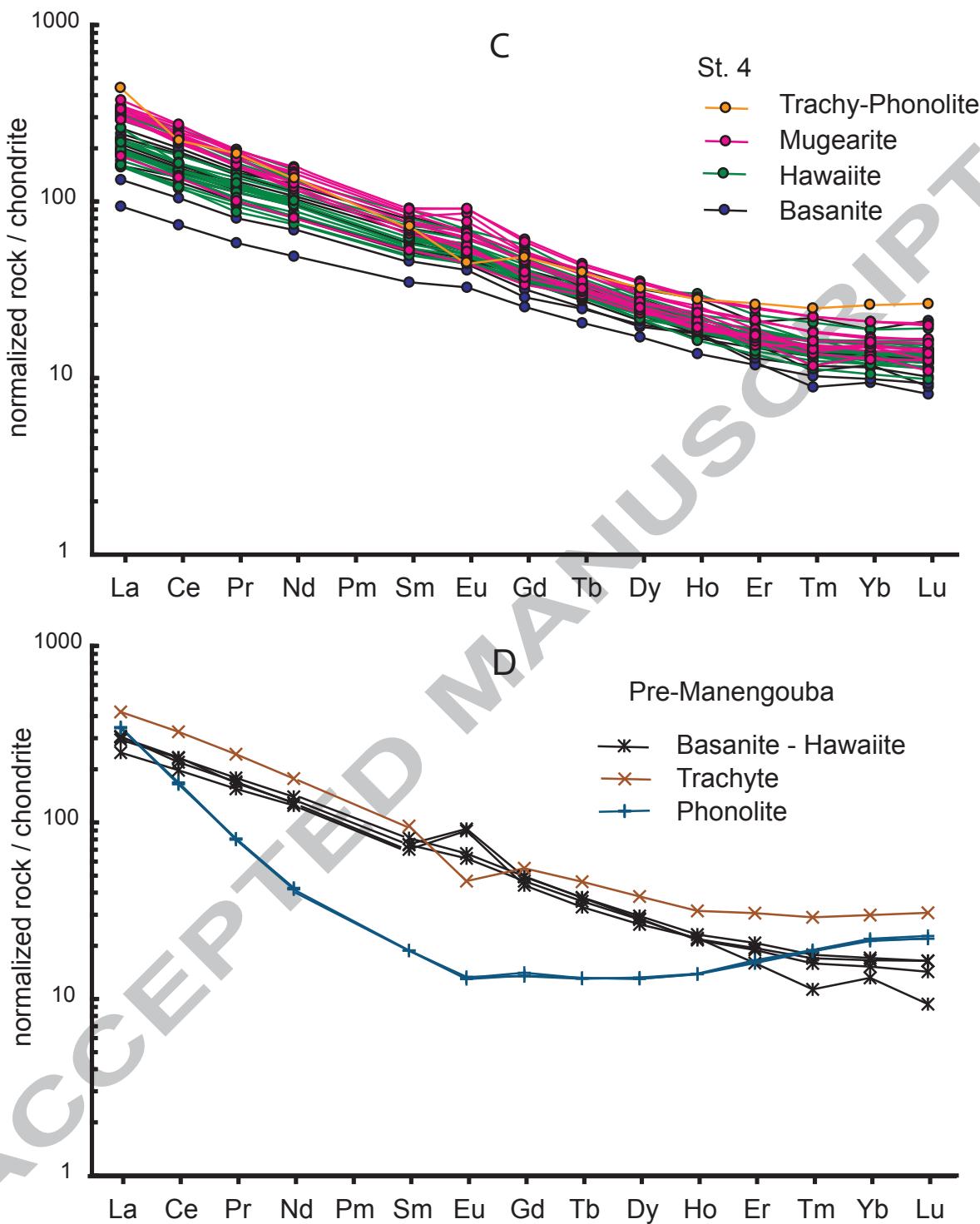
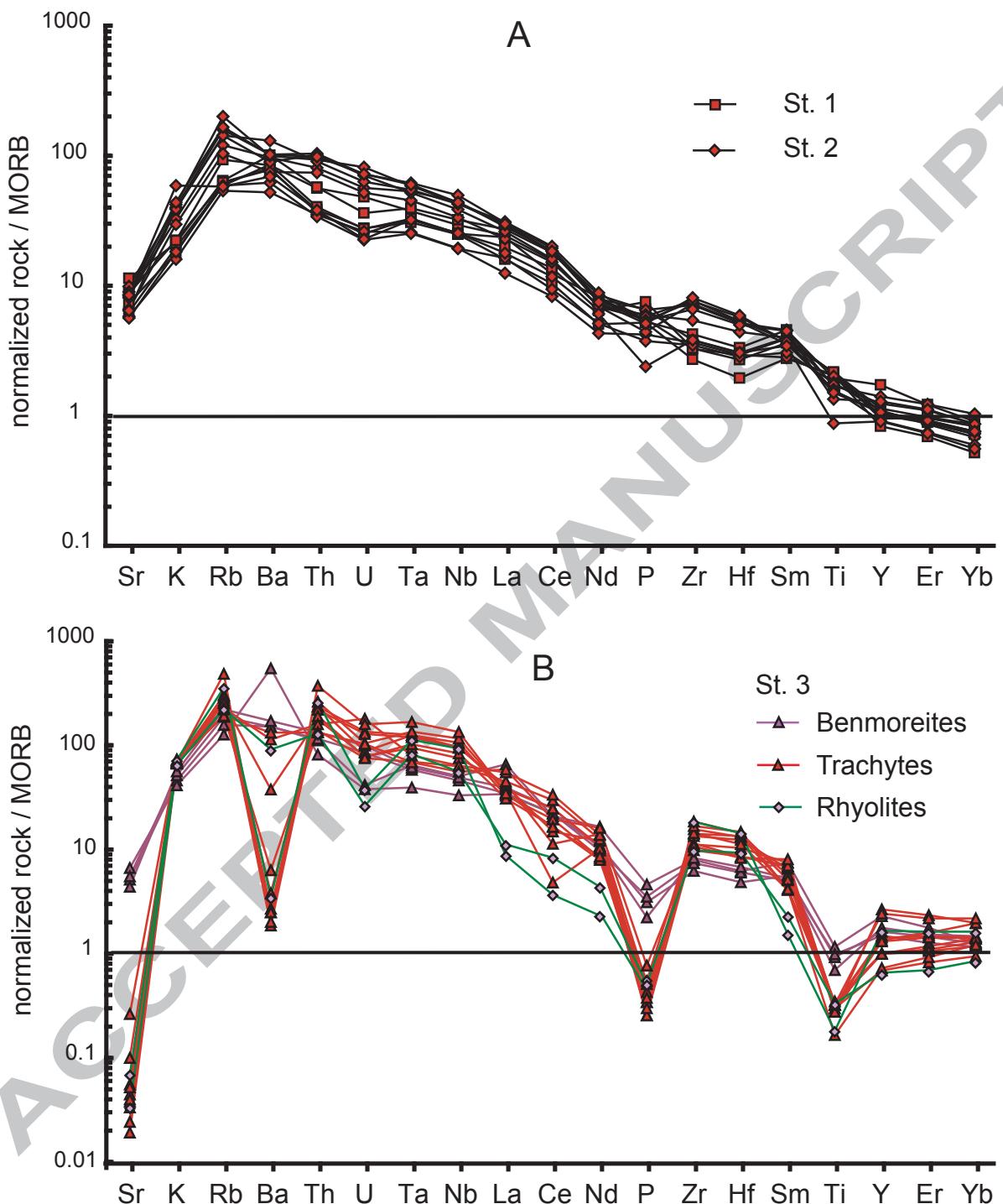


Fig. 18

ACCEPTED MANUSCRIPT



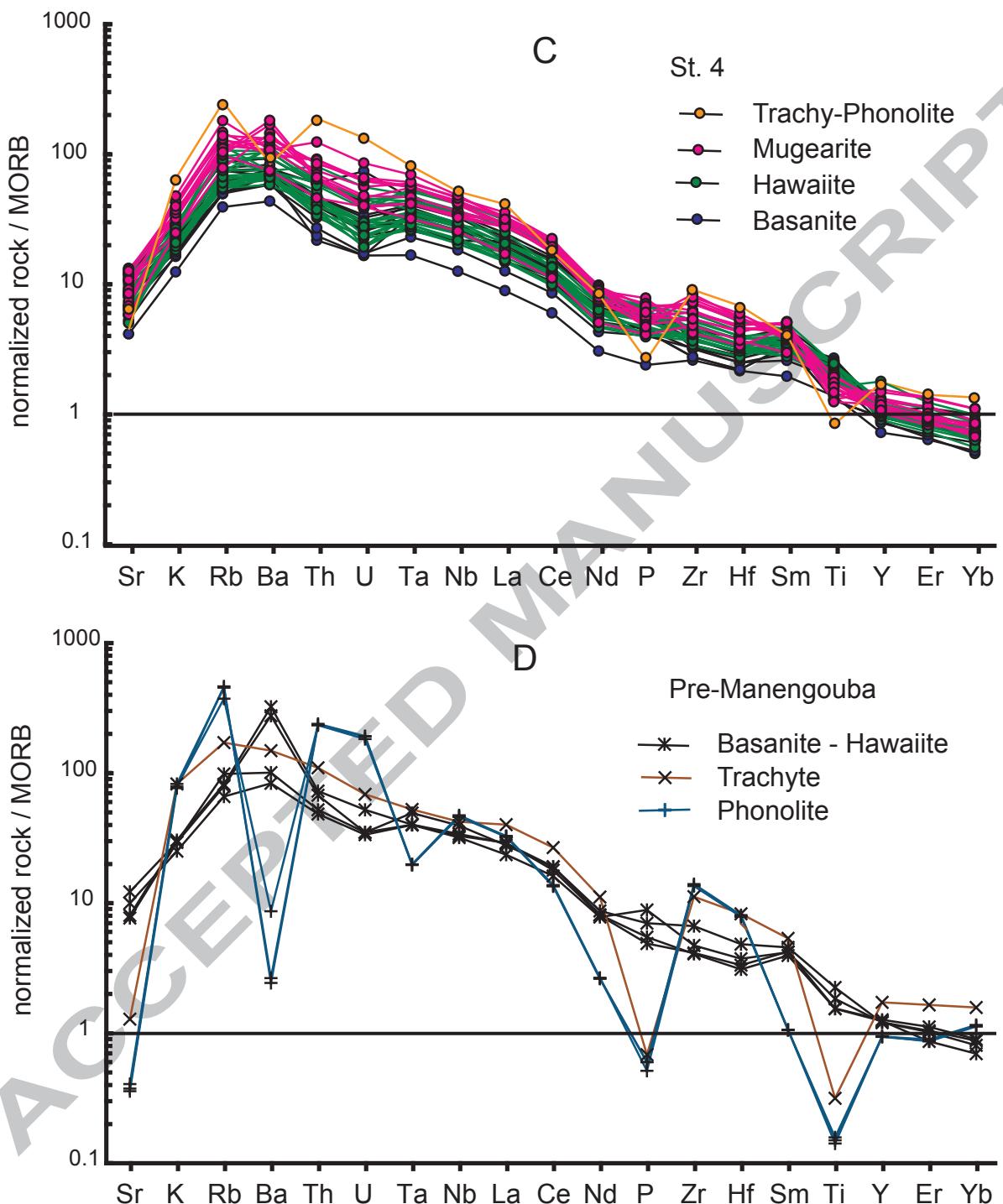


Fig. 19

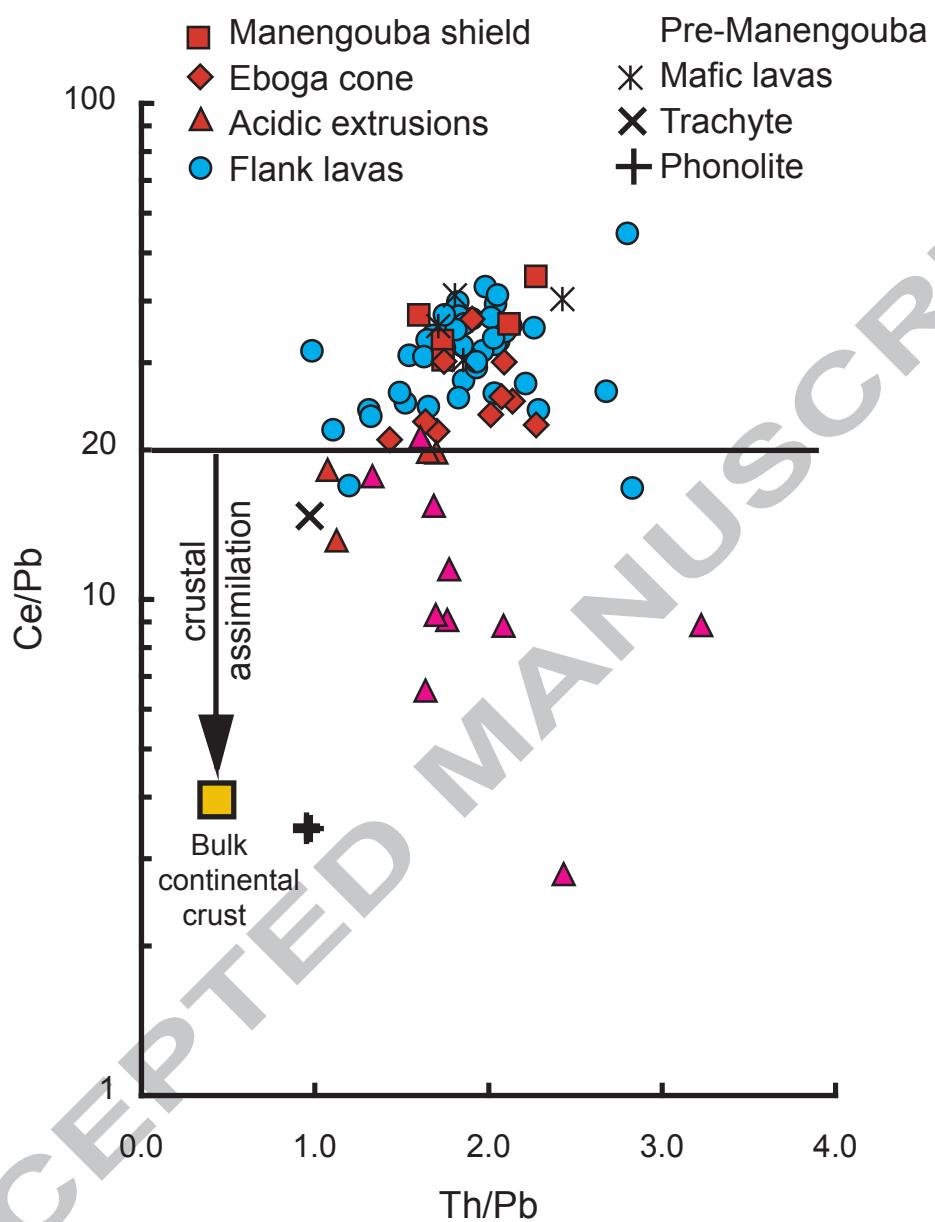


Fig. 20

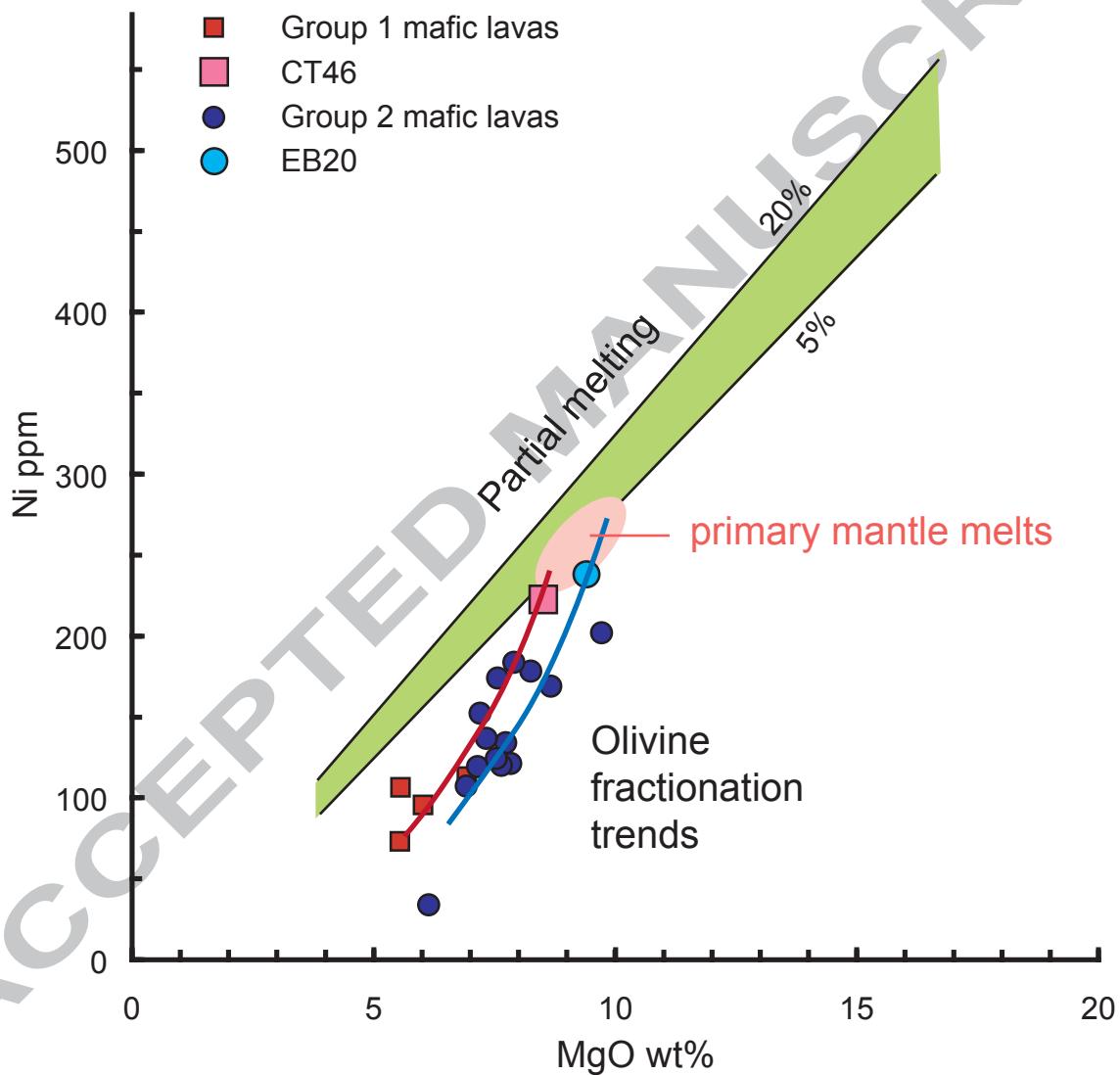


Fig. 21

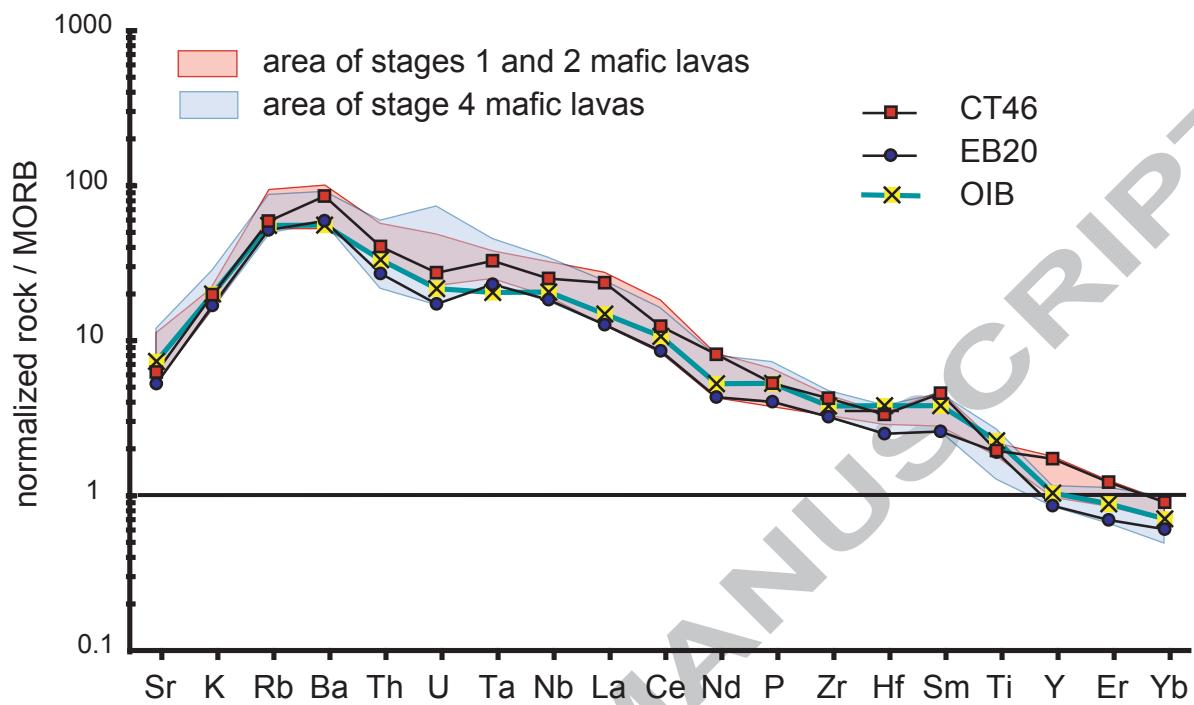


Fig. 22

ACCEPTED MANUSCRIPT

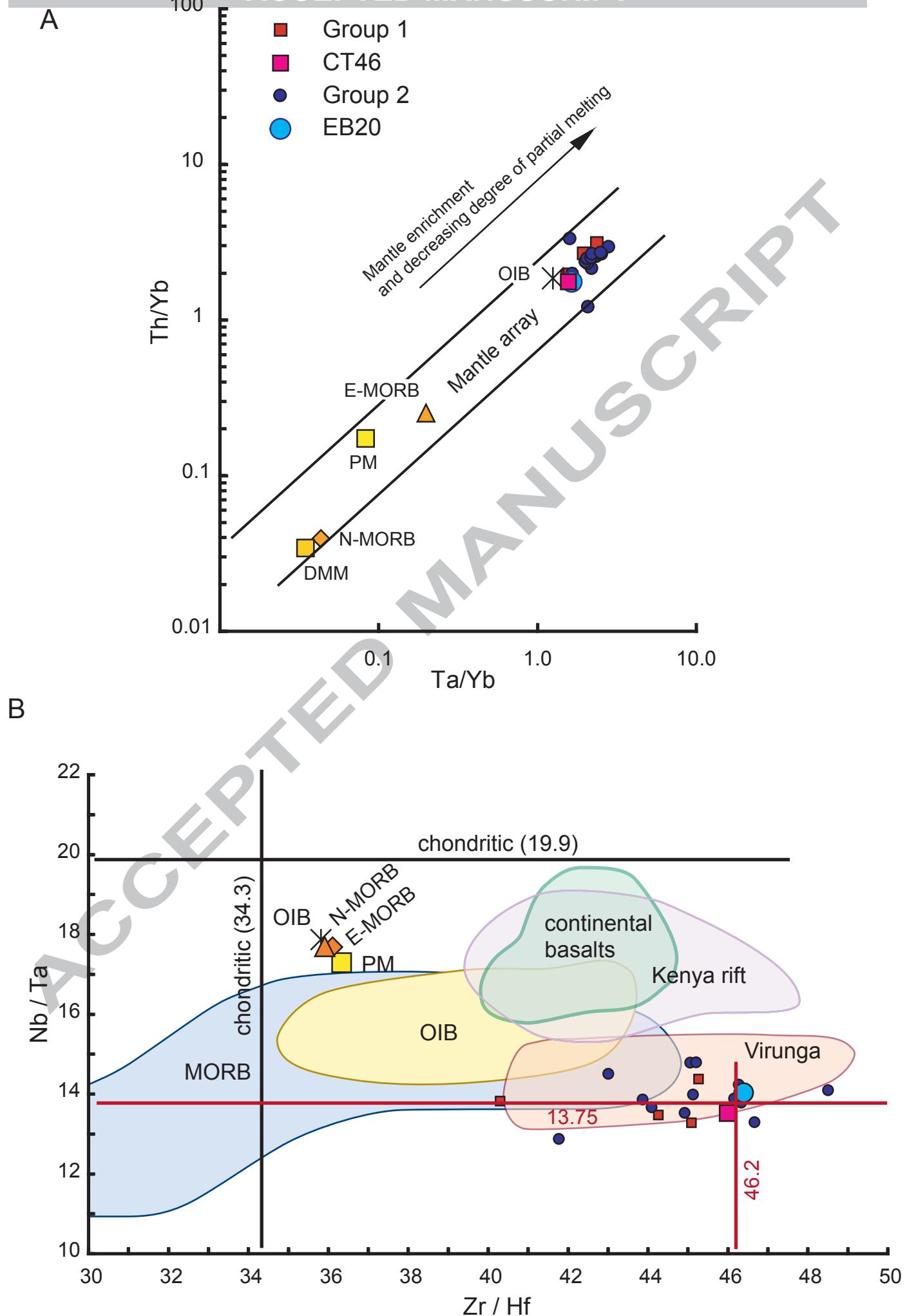


Fig. 23

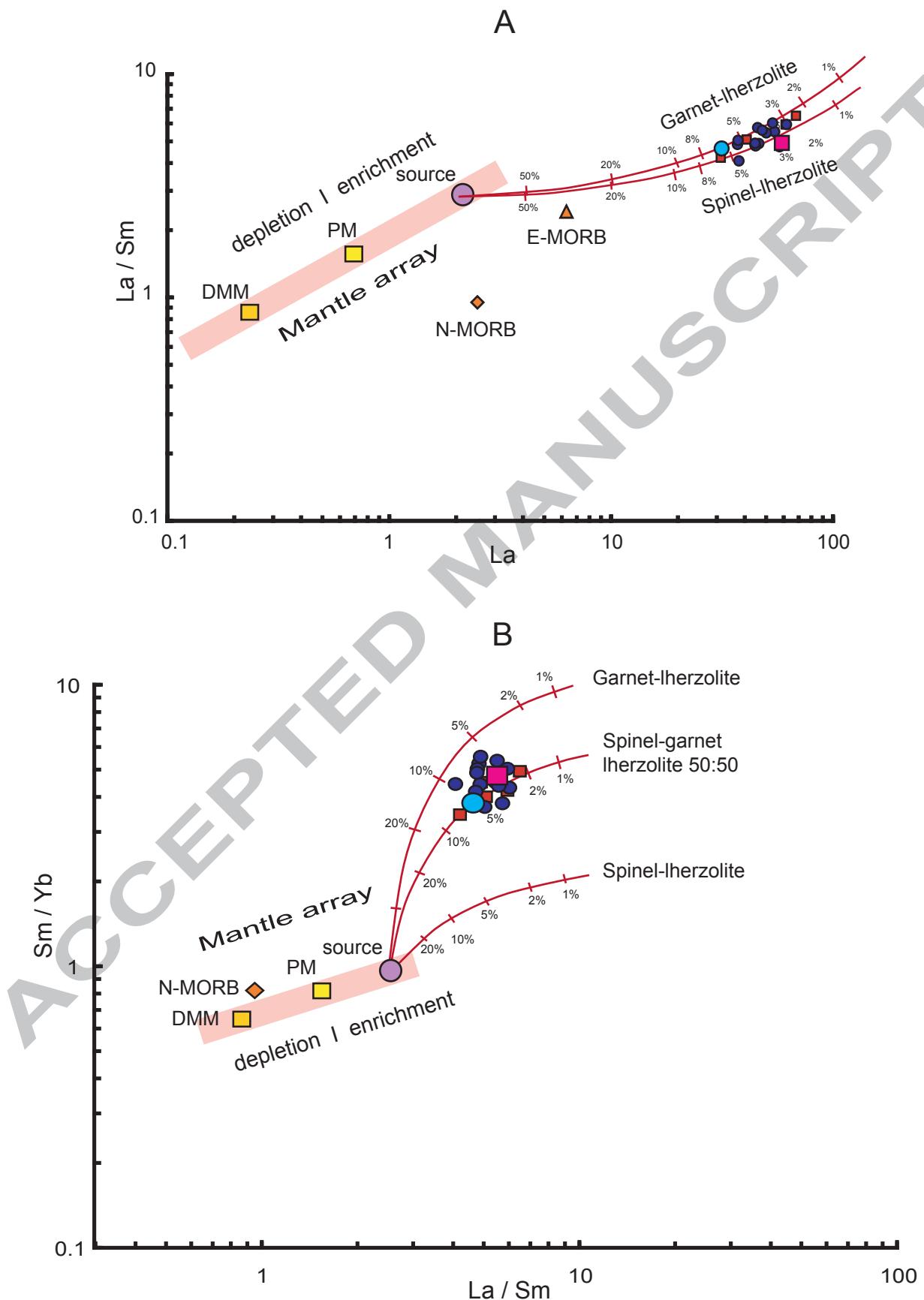


Fig. 24

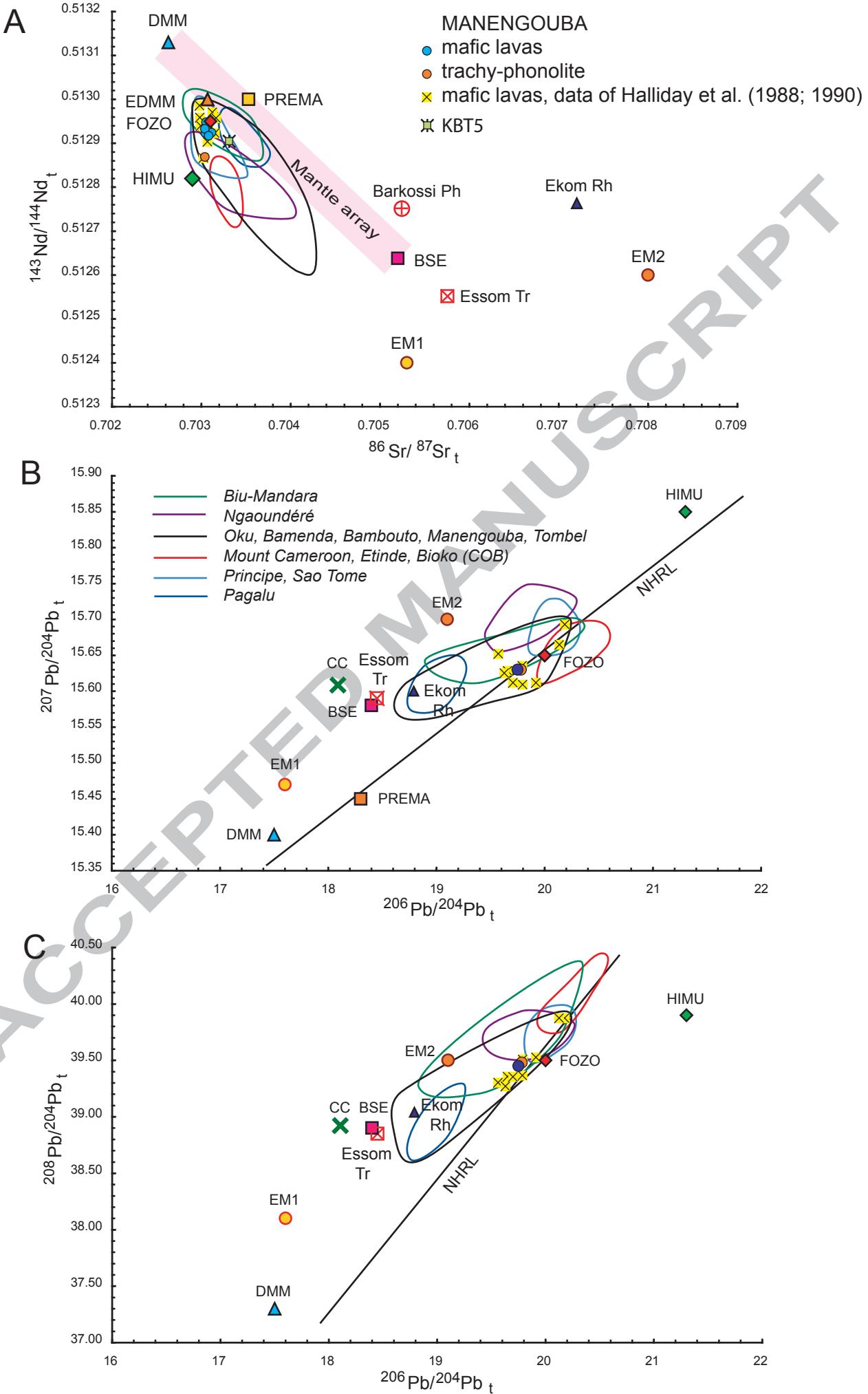
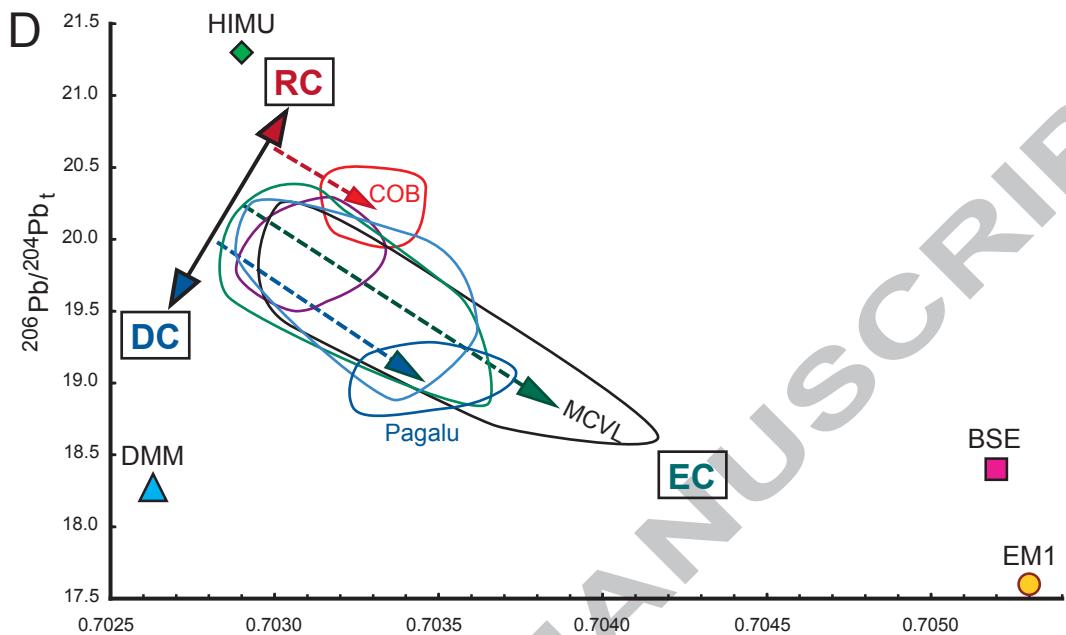


Fig. 24



1409

1410 **The Mount Manengouba, a complex volcano of the Cameroon Line: Volcanic history,**
1411 **petrological and geochemical features by André Pouclet et al.**

1412

1413

Highlights

1414

1415 The volcanic history of the Manengouba fit with four stages between 1.55 and 0.11 Ma.
1416 The volume of the volcano is calculated at $320 \text{ km}^3 \pm 5\%$.

1417 The magma was generated with 3 to 6% of partial melting of a fairly enriched source.

1418 Melting of the source occurred in the lithospheric spinel to garnet transition zone.

1419 Three source components are distinguished: depleted, radiogenic, and enriched.

1420

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Table 4. Selected chemical analyses of minerals. A: Olivine

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Table 4. Selected analyses of minerals. B, Magnetite

Table 4. Selected analyses of minerals. C, Ilmenite

Manengouba, stage 2				Manengouba, stage 3			Manengouba, stage 4			Pre-Man	
#	NS2	EB30	Eb11	Eb11	EL4	Eb17	KNS1	Eb20	Eb14	Eb14	PL5
Petrographica l facies	H	M	M	M	Bn	Bn	Tr	Alk-B	M	M	M
Mineral type	microcryst	phenocryst	phenocryst	microcryst	phenocryst	microcryst	microphenocryst	phenocryst	phenocryst	phenocryst	microphenocryst
SiO ₂	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.03
TiO ₂	49.71	50.17	49.66	48.22	48.92	51.12	47.68	47.92	49.88	49.15	48.85
Al ₂ O ₃	0.36	0.14	0.20	0.43	0.47	0.04	0.03	0.08	0.00	0.03	0.40
Cr ₂ O ₃	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.10
FeO	41.92	42.46	45.39	48.20	44.44	44.69	45.68	44.30	46.89	46.64	42.88
MnO	0.63	0.77	0.94	0.81	0.64	1.38	2.09	1.32	0.80	0.89	0.44
MgO	4.89	4.01	3.42	1.81	5.45	0.86	0.00	1.94	1.10	1.14	5.02
CaO	0.03	0.03	0.03	0.03	0.05	0.05	0.00	0.06	0.00	0.00	0.08
Total	97.54	97.58	99.67	99.50	99.97	98.14	95.48	95.67	98.67	98.00	97.80
Si	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	0.000	0.001
Al	0.021	0.008	0.012	0.025	0.027	0.002	0.002	0.005	0.000	0.002	0.023
Ti	1.854	1.885	1.834	1.804	1.770	1.962	1.891	1.867	1.898	1.882	1.815
Fe ³⁺	0.263	0.218	0.315	0.359	0.424	0.072	0.217	0.258	0.204	0.225	0.334
Fe ²⁺	1.476	1.556	1.549	1.647	1.364	1.836	1.798	1.661	1.781	1.761	1.437
Mg	0.361	0.299	0.250	0.134	0.391	0.065	0.000	0.150	0.083	0.087	0.370
Mn	0.026	0.033	0.039	0.034	0.026	0.060	0.093	0.058	0.034	0.038	0.018
Cr	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.004
Ca	0.001	0.002	0.002	0.002	0.003	0.003	0.000	0.003	0.000	0.000	0.004
Total	4.002	4.000	4.001	4.003	4.002	3.998	4.000	4.001	4.000	4.001	4.002

Table 4. Selected surfaces of minerals. D. Dommergues

Table 4. Selected analyses of minerals. E, Amphibole

#	Manengouba, stage 2				Manengouba, stage 4				Adv			
	Petrographical facies	EB11 M Edenite	Eb10 M Kaersutite	Eb10 M phenocryst Kaersutite	Eb10 M phenocryst Kaersutite	EK1C H phenocryst Kaersutite	EK1C H phenocryst Kaersutite	KOS7 M microcryst Edenite	EE4 M phenocryst Kaersutite	EE4 M microcryst Kaersutite	KK3A M phenocryst Kaersutite	KK3A M phenocryst Edenite
SiO ₂	45.40	40.84	40.24	39.59	39.53	39.57	44.73	40.79	40.20	39.81	41.99	
TiO ₂	2.10	6.03	5.85	6.16	5.20	5.26	3.41	4.87	5.14	5.19	4.42	
Al ₂ O ₃	6.71	13.03	12.34	13.65	12.85	12.76	7.27	12.39	14.40	13.22	10.62	
Cr ₂ O ₃	0.00	0.02	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.08	
FeO	10.66	11.24	11.11	10.63	11.55	11.14	10.56	11.00	10.35	10.73	13.93	
MnO	0.39	0.21	0.22	0.17	0.12	0.33	0.24	0.10	0.19	0.22	0.31	
MgO	16.42	12.25	13.12	12.09	13.10	13.16	15.84	13.36	13.08	13.69	12.64	
CaO	10.45	11.65	11.77	11.96	11.77	11.84	10.64	11.84	11.17	10.79	10.43	
Na ₂ O	2.88	2.69	3.14	2.81	2.90	2.78	3.58	2.77	2.67	3.00	2.93	
K ₂ O	1.17	0.88	0.89	0.95	1.02	1.01	1.23	0.83	0.94	0.98	1.01	
Total	96.17	98.84	98.68	98.06	98.05	97.84	97.52	97.95	98.14	97.62	98.34	
Si	6.661	5.993	5.930	5.888	5.847	5.862	6.569	6.009	5.849	5.825	6.159	
Al ^{IV}	1.160	2.007	2.070	2.112	2.153	2.138	1.259	1.991	2.151	2.175	1.835	
Ti	0.179	0.000	0.000	0.000	0.000	0.000	0.172	0.000	0.000	0.000	0.006	
Total	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	
Al ^{VII}	0.000	0.247	0.073	0.281	0.088	0.088	0.000	0.160	0.318	0.105	0.000	
Ti	0.053	0.665	0.648	0.689	0.579	0.586	0.205	0.539	0.562	0.571	0.481	
Cr	0.000	0.002	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.010	
Fe ³⁺	0.721	0.000	0.000	0.000	0.152	0.131	0.248	0.068	0.296	0.508	0.559	
Fe ²⁺	0.586	1.379	1.369	1.322	1.277	1.248	1.048	1.287	0.963	0.805	1.150	
Mn	0.049	0.026	0.027	0.021	0.015	0.042	0.030	0.012	0.023	0.027	0.038	
Mg	3.591	2.680	2.882	2.680	2.889	2.905	3.468	2.933	2.837	2.985	2.763	
Total	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	5.000	
Ca	1.642	1.832	1.858	1.906	1.865	1.879	1.675	1.869	1.741	1.691	1.639	
Na	0.358	0.168	0.142	0.094	0.135	0.121	0.325	0.131	0.259	0.309	0.361	
Total	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	
Na	0.461	0.597	0.756	0.716	0.697	0.677	0.694	0.660	0.494	0.541	0.471	
K	0.218	0.165	0.167	0.180	0.193	0.191	0.230	0.156	0.174	0.183	0.188	
Total	0.679	0.762	0.923	0.896	0.890	0.868	0.924	0.816	0.669	0.723	0.659	

Table 4. Selected analyses of minerals. F, Mica

	Manengouba, stage 2		Manengouba, stage 4	
#	Eb11	Eb11	KOS7	KOS7
Petrographical facies	M	M	M	M
Mineral type	phenocryst	phenocryst	microphenocrys	microcryst
SiO ₂	40.56	41.02	39.60	39.27
TiO ₂	3.92	3.90	4.99	5.74
Al ₂ O ₃	12.33	11.88	11.97	12.36
Cr ₂ O ₃	0.00	0.11	0.00	0.00
FeO	9.56	8.97	9.51	10.02
MgO	20.59	20.61	19.60	18.54
CaO	0.08	0.00	0.01	0.03
MnO	0.11	0.00	0.13	0.11
Na ₂ O	0.99	0.84	1.40	1.02
K ₂ O	9.00	9.31	8.49	8.60
Total	97.14	96.64	95.70	95.69
Si	3.152	3.196	3.128	3.107
Al ^{IV}	0.848	0.804	0.872	0.893
Total	4.000	4.000	4.000	4.000
Al ^{VI}	0.282	0.287	0.241	0.260
Ti	0.229	0.229	0.296	0.342
Fe	0.621	0.584	0.628	0.663
Mg	2.386	2.394	2.308	2.187
Mn	0.007	0.000	0.009	0.008
Total	3.525	3.493	3.482	3.459
K	0.894	0.927	0.857	0.870
Na	0.149	0.127	0.215	0.156
Total	1.044	1.054	1.072	1.026

Table 4. Selected analyses of minerals. G, Feldspars

Manengouba, stage 1												Manengouba, stage 2												Manengouba, stage 3												Manengouba, stage 4											
#	CT46	MAB2	MA2B	MA2B	MA2B	MA2B	ML2	ML2	NS2	KEB30	EB10	KEB30	ELG4	EB11	EB17	EL4	KEB3	EL4	KNS1	KPT7	KEB26	G01	EM2	EM2	EM2	EIR20	CT41	CT53	SP5	SA1b	SP5	K057	EB14	KK3A													
Petrographical faces	alk-B	Na-Bs	Na-Bs	Na-Bs	Na-Bs	Na-Bs	H	H	H	M	M	M	M	M	Bn	Bn	Bn	Tr	Tr	Tr	Ank	Na-Bs	Na-Bs	Na-Bs	Bs	H	H	H	H	M	M	M	M	M	M	M											
Mineral type	phenocryst	phenocryst	phenocryst	microcryst	microcryst	microcryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst	phenocryst			
SiO ₂	50.55	50.02	50.79	52.90	54.49	56.41	52.87	55.03	54.91	53.07	58.16	56.95	62.23	52.44	56.93	58.41	56.95	58.34	65.39	65.78	64.56	50.65	51.35	51.74	54.02	58.12	51.20	54.16	53.68	54.55	55.25	52.61	54.67	57.28	61.34												
Al ₂ O ₃	31.66	31.97	29.79	30.11	28.51	28.25	21.85	20.19	28.05	27.94	27.11	25.07	21.68	30.06	27.75	26.55	25.07	24.69	18.69	18.67	18.64	30.28	29.91	29.70	26.97	26.33	30.32	30.28	28.87	28.09	27.83	28.04	27.86	27.49	25.43	23.32											
Fe ₂ O ₃	1.05	0.98	0.82	0.93	0.53	0.43	0.33	0.56	0.95	0.48	0.50	0.50	0.16	0.56	0.46	0.71	0.50	0.46	0.16	0.00	0.25	0.64	0.90	1.13	1.75	0.20	0.59	0.52	0.34	0.48	0.30	0.64	0.64	0.64	0.64	0.64											
CaO	13.02	13.02	12.16	11.39	10.48	9.63	13.22	10.66	9.88	10.24	8.31	7.53	12.16	12.29	8.88	7.88	7.53	6.37	0.12	0.01	0.19	13.54	12.67	12.43	10.45	8.77	11.75	11.25	9.88	9.54	10.47	10.78	9.78	9.20	5.06												
Na ₂ O	3.71	3.55	3.98	4.52	5.22	5.69	4.33	5.30	5.49	5.11	6.46	6.66	8.35	4.20	6.02	6.54	6.66	6.92	7.11	7.43	7.42	3.62	3.86	3.94	4.86	5.48	5.64	4.91	5.56	5.64	6.11	8.00	8.00	8.00													
K ₂ O	0.01	0.26	0.25	0.31	0.36	0.53	0.23	0.31	0.40	0.43	0.66	0.64	1.74	0.34	0.57	0.57	0.64	0.99	6.23	5.91	5.48	0.25	0.37	0.38	0.79	0.70	0.25	0.32	0.35	0.59	0.34	0.33	1.10	0.63													
Total	100.00	99.80	97.78	100.16	99.59	100.94	100.27	100.91	99.68	97.27	101.20	97.35	97.32	99.89	100.61	100.66	97.73	97.77	97.81	96.54	98.98	99.06	99.32	98.84	100.41	98.29	100.19	98.84	99.19	99.19	97.07	98.13	99.29	99.29	99.29	99.29	99.29										
Si	2.300	2.284	2.359	2.393	2.470	2.515	2.389	2.462	2.487	2.464	2.579	2.623	2.836	2.382	2.542	2.600	2.623	2.667	2.989	2.997	2.981	2.332	2.359	2.370	2.482	2.482	2.596	2.361	2.446	2.469	2.506	2.452	2.508	2.597	2.754												
Al	1.698	1.720	1.631	1.605	1.53	1.484	1.608	1.532	1.497	1.529	1.417	1.361	1.169	1.461	1.393	1.361	1.330	1.007	1.003	1.014	1.643	1.619	1.604	1.461	1.387	1.384	1.648	1.537	1.523	1.515	1.499	1.531	1.487	1.359	1.359	1.359	1.359										
Fe ³⁺	0.036	0.035	0.029	0.032	0.018	0.014	0.011	0.019	0.032	0.017	0.017	0.017	0.006	0.019	0.015	0.024	0.017	0.016	0.000	0.000	0.022	0.031	0.039	0.061	0.007	0.020	0.020	0.020	0.018	0.017	0.017	0.010	0.022	0.022	0.022												
Ca ₃	0.635	0.637	0.605	0.652	0.509	0.460	0.597	0.511	0.479	0.510	0.395	0.372	0.154	0.598	0.425	0.376	0.372	0.312	0.000	0.009	0.666	0.624	0.610	0.514	0.420	0.581	0.544	0.502	0.482	0.464	0.543	0.481	0.447	0.447	0.447	0.447	0.447										
Na ₃	0.327	0.314	0.359	0.396	0.459	0.492	0.379	0.460	0.482	0.460	0.555	0.595	0.737	0.370	0.521	0.565	0.595	0.614	0.630	0.657	0.664	0.323	0.344	0.350	0.433	0.545	0.374	0.428	0.474	0.481	0.496	0.444	0.495	0.537	0.696												
K	0.001	0.015	0.018	0.021	0.030	0.014	0.018	0.023	0.025	0.037	0.037	0.010	0.020	0.033	0.032	0.037	0.058	0.364	0.344	0.324	0.015	0.022	0.024	0.046	0.048	0.015	0.018	0.020	0.023	0.020	0.020	0.019	0.037	0.037	0.037	0.037											
Total	4.997	5.004	4.998	4.999	4.999	4.998	5.001	5.001	5.005	4.998	5.005	5.002	5.001	4.998	4.997	4.998	5.000	5.002	5.001	5.000	4.999	4.995	4.997	4.999	4.997	5.007	5.000	4.998	4.996	4.998	5.000	5.000	4.999	4.999	4.999	4.999	4.999										
% Ab	34.00	32.56	36.64	41.02	46.41	50.98	38.34	46.42	48.96	46.24	54.26	59.26	74.25	37.45	53.26	58.03	59.26	62.41	63.00	65.57	66.62	32.13	34.76	36.35	43.57	54.23	38.57	43.21	47.58	48.82	50.48	44.08	49.74	52.63	69.44												
% An	65.94	65.91	61.86	57.12	51.48	46.84	60.29	51.70	48.69	51.21	39.98	37.02	15.55	60.55	43.41	38.64	31.74	0.57	0.06	0.92	66.41	63.05	62.11	51.77	41.79	59.19	54.93	50.37	49.01	47.20	53.93	48.33	43.79	24.27													
% Or	0.06	1.57	1.49	1.86	2.11	3.08	1.37	1.78	2.35	2.55	3.79	3.72	10.20	2.00	3.33	3.33	3.72	3.55	36.43	34.36	32.46	1.46	2.20	2.27	4.67	3.98	3.42	1.86	2.05	2.07	2.32	1.99	1.92	3.58													

Table 5. Chemical analyses of the rocks

		Undetermined relationships												Manengouba, stage 4											
Eboga E slope LG3B extrusion	Elongoum Nkongsamba CT216	Elongoum summit KNS1	Eboga E slope LGSE	Elongoum pike CT124	Eboga SW caldera KEB26	Ekom	Ekom	Ngol	Nzoh cone	Mkon	Njom	Manjo	Caldera	Djou Sch	Etam Manjo	Passim - Ekoh	Caldera	SE Ndoungoué	Manengouba vill.	Melong	Melong	Ekambeng	Caldera		
Tr	Tr	Tr	Tr	Tr	Tr	Rh	Rh	Ank	Na-Bs	S Mbanguel	S Bangem	Bs	W floor	EB20	EM2	CT55	W floor	CT44	KCTI	KME2A	CT47	flow	E Bangem CT50i	NW Floor KEB33	
65.89	65.77	65.80	65.33	64.37	68.27	67.58	71.36	44.84	43.32	43.67	44.41	44.42	48.07	46.06	44.64	44.91	47.92	47.50	46.38	47.38	47.77	47.35	49.30		
0.41	0.41	0.35	0.41	0.35	0.21	0.42	0.23	3.01	3.29	3.43	3.10	3.25	1.75	3.10	3.14	3.24	2.41	1.63	2.84	2.50	2.52	2.91	2.53		
13.63	14.17	13.41	15.75	16.91	15.30	13.96	12.48	13.93	14.76	14.42	14.21	14.99	12.48	15.17	15.01	15.17	13.72	16.83	14.67	14.53	15.28	15.09	14.39		
6.65	6.14	6.22	4.44	3.95	4.27	5.47	3.94	13.47	14.46	14.64	14.16	14.15	12.76	13.32	14.07	13.52	12.41	11.25	13.53	13.30	12.48	12.62	12.06		
0.18	0.18	0.33	0.12	0.07	0.115	0.16	0.05	0.17	0.20	0.20	0.19	0.18	0.20	0.20	0.17	0.17	0.16	0.17	0.20	0.19	0.17	0.16	0.17		
0.04	0.14	0.03	0.13	0.25	0.07	0.04	0.00	9.72	7.74	8.26	8.67	7.84	10.63	7.15	7.65	7.55	9.41	6.15	7.34	7.91	7.21	6.92	7.57		
0.44	0.71	0.39	0.60	0.48	0.46	0.54	0.13	9.69	10.4	10.01	9.93	9.55	8.33	9.61	9.48	9.28	8.80	10.77	9.10	9.09	9.12	8.56	8.68		
6.46	6.10	5.43	7.24	7.18	6.22	6.49	4.78	3.21	3.48	3.41	3.39	3.71	3.19	3.40	3.79	3.57	3.36	3.47	3.48	3.68	3.78	3.69	3.66		
4.89	4.86	4.89	5.23	5.28	4.99	4.68	5.26	1.18	1.38	1.45	1.53	1.59	0.90	1.30	1.63	1.71	1.22	2.08	1.28	1.33	1.44	1.56	1.44		
0.04	0.04	0.03	0.06	0.09	0.04	0.06	0.00	0.53	0.86	0.7	0.66	0.70	0.28	0.66	0.71	0.63	0.47	0.51	0.75	0.65	0.60	0.61	0.48		
1.09	0.77	2.34	0.36	1.00	0.13	0.29	1.59	-0.06	-0.23	-0.61	-0.51	-0.72	1.16	-0.04	-0.66	0.22	-0.16	-0.37	-0.28	-0.66	-0.41	-0.06	-0.08		
99.72	99.29	99.22	99.67	99.93	100.08	99.69	99.82	99.66	99.58	99.74	99.66	99.73	99.93	99.66	99.97	99.72	99.99	99.99	99.99	99.99	99.96	100.22	100.20		
83.99	85.50	86.17	88.13	90.48	91.25	86.65	91.20	29.12	29.42	29.67	30.35	32.63	33.16	33.20	33.46	33.83	34.48	34.76	34.72	35.50	36.96	37.65	38.74		
0.0	0.0	0.0	4.0	256	244	251	260	265	159.9	228.2	260	253	198	306.8	202.6	205.1	199	204.6	200.5	205.1	199	204.6	200.5		
1.0	11.12	2.0	10.37	283	197.3	221	219.8	140	400.7	165.8	159	146	348	54.04	200	295.8	227	158.8	266.7	227	158.8	266.7	227		
0.2	0.31	0.41	0.3	0.44	0.30	0.3	0.25	49.0	44.3	47.1	47.06	46.6	57.8	45.29	45.1	49.2	45.1	39.85	43.59	47.1	43.6	44.14	42.21		
1.0	8.11	5.0	4.0	202.0	134.0	178.0	169.0	121.0	288.2	119.0	120.0	124.0	238.0	33.89	136.7	183.6	152.00	107.00	173.9	152.00	107.00	173.9			
2.68	11.97	4.22	5.19	52.5	66.79	111.0	74.01	53.68	45.23	49.79	53.96	52.5	66.7	128.2	53.75	78.54	45.4	37.85	72.5	72.5	72.5	72.5			
37.44	36.23	35.5	32.09	34.44	37.58	35.63	38.60	21.53	21.43	22.4	21.24	23.79	18.51	23.00	24.91	24.45	21.10	22.10	21.69	24.70	25.50	23.62	22.86		
143.00	143.00	143.2	128.00	107.9	273.0	125.46	200.4	28.00	34.00	27.82	42.00	41.00	22.00	23.0	42.0	42.0	29.00	48.92	27.95	32.46	34.50	32.45	35.97		
6.4	4.7	3.41	9.04	23.69	3.61	3.0	6.20	599.0	854.0	779.0	725.0	788.0	372.4	748.3	767.0	957.0	473.0	1034.0	716.3	745.5	735.0	716.0	524.2		
40.10	27.93	74.80	36.69	20.32	18.46	46.58	24.7	32.7	31.2	29.00	30.6	20.26	28.15	30.4	31.8	26.5	26.5	27.38	27.50	28.41	28.41	28.41	28.41		
831.0	1062.0	846.1	729.0	791.7	1240.9	727.0	1361.0	236.0	278.0	249.0	230.0	325.0	192.2	252.0	320.0	351.0	238.0	204.1	241.8	317.9	318.0	282.3	285.8		
175.00	195.00	147.4	149.0	130.1	313.5	129.78	217.6	50.66	64.99	68.18	75.54	29.36	60.55	77.78	80.00	42.65	50.44	57	58.00	59.8	59.15	47.88	47.88		
237.0	15.76	39.98	716.0	832.0	12.68	577.12	21.63	367.0	482.8	431.0	425.92	476.0	274.7	443.2	488.0	524.0	374.0	586.8	443.1	399.8	406.0	435.1	448.4		
21.16	23.11	17.49	17.56	30.37	19.00	29.45	5.1	6.00	5.70	4.44	5.75	7.44	5.75	7.79	5.1	4.52	6.87	7.80	6.20	6.19	6.20	6.19			
12.50	13.49	9.20	10.57	9.06	22.16	10.94	14.96	3.56	4.86	4.48	5.13	5.36	2.21	4.37	6.04	5.41	3.04	3.41	4.17	4.18	4.42	4.23	3.45		
12.99	13.49	12.60	11.92	9.51	13.90	3.93	3.77	2.32	2.74	2.66	2.72	3.18	1.38	3.17	4.7	2.88	2.93	5.94	3.04	2.82	2.87	2.40	2.78		
21.24	22.86	16.76	19.18	16.04	44.83	15.61	31.37	3.90	4.78	2.62	5.61	5.65	2.83	4.90	7.16	5.71	3.24	7.12	5.051	4.85	5.31	4.58	4.15		
3.69	3.64	3.55	8.48	4.85	7.45	7.49	1.24	1.80	1.11	1.19	0.78	1.53	1.60	0.78	1.20	3.49	1.34	0.81	2.03	1.24	1.42	1.07	1.06		
108.00	77.09	112.5	138.00	147.1	86.70	27.90	21.96	37.19	46.40	37.78	45.82	54.73	22.29	50.12	57.44	61.80	31.54	53.53	48.05	44.63	44.90	44.56	37.37		
85.00	125.6	223.2	253.00	146.8	123.30	62.59	27.5	79.00	93.00	84.14	90.00	114.00	45.13	98.25	117.00	123.00	64.25	100.60	95.28	91.72	93.10	88.16	72.71		
27.51	16.69	24.43	27.48	34.74	20.36	8.29	47.86	9.32	12.13	10.42	10.79	13.15	5.44	11.27	13.54	14.10	7.48	11.85	11.14	11.30	11.60	10.98	8.70		
102.5	58.03	91.29	100.4	117.5	62.54	32.00	18.96	37.63	49.00	43.31	48.18	51.96	22.35	45.67	57.51	55.40	31.46	45.97	43.67	45.89	47.20	44.26	34.97		
19.54	102	17.92	18.43	21.24	10.33	6.00	4.04	7.70	9.50	9.27	7.98	9.92	2.27	3.04	1.83	2.94	3.80	3.53	2.30	2.64	2.85	3.07	3.05		
3.39	1.13	2.78	3.15	4.39	0.32	1.70	0.77	2.48	3.13	2.97	2.67	3.04	1.83	2.94	3.80	3.53	2.30	2.64	2.85	3.07	3.05	2.53			
14.02	7.71	15.58	15.51	6.24	4.86	4.76	6.33	8.22	7.0	7.46	7.95	5.03	7.98	9.96	9.15	5.70	7.04	7.42	7.88	8.11	7.16	6.86			
2.03	1.22	2.43	2.36	2.14	1.07	0.74	1.10	0.91	1.21	1.11	1.05	1.13	0.74	1.12	1.47	1.18	0.89	0.99	1.05	1.12	1.06	1.03			
10.52	6.69	13.63	12.98	10.93	5.83	4.14	8.11	6.91	6.15	5.89	6.05	4.19	5.95	7.97	6.55	4.95	5.21	5.60	5.85	5.72	5.34	5.62			
2.02	1.16	2.55	2.74	1.66	0.95	0.73	1.65	0.97	1.21	1.06	1.07	1.13	0.75	1.03	1.54	1.14	0.98	0.92	0.97	1.00	1.07	0.89			
4.35	3.14	6.97	6.47	4.26	2.97	4.83	1.96	2.74	2.72	2.39	2.51	1.90	2.59	3.32	2.71	2.17	2.57	2.48	2.45	2.38	2.19	2.57			
0.67	0.49	0.98	0.97	0.63	0.47	0.34	0.74	0.22	0.34	0.36	0.34	0.27	0.25	0.34	0.54	0.38	0.33	0.33	0.34	0.28	0.24	0.34			
4.39	3.59	6.01	6.66	4.29	3.70	2.59	4.96	1.52	2.22	2.16	2.18	1.91	2.11	3.02	2.14	1.85	2.13	2.03	1.92	2.00	1.69	2.09			
0.65	0.58	0.88	0.92	0.66	0.60	0.44	0.75	0.20	0.35	0.35	0.31	0.22	0.23	0.30	0.52	0.30	0.25	0.32							

ACCEPTED MANUSCRIPT

NW-Bangem	Elooh	Ngol	Caldera	SE Nkongsamba	Bayon	Ndripsi I	Mboassoum	Ndom	Manengolé	Manengolé	Caldera	Caldera	Caldera	Nkongsamba	N Nkongsamba	Caldera	NE Nkongsamba	Elom	Badjoungue			
	Nyabang	Core SE	Ngabang	CT28	SP5	CT153	CT108	ND1	NE Manjo	NE Manjo	SE floor	SE floor	SE floor	Ossoua river	EB14	EE4	CT52	KG3	S Eboga	CT118	CT51	CT60
	CT104	ER1C	CT41	KCE2	flow	flow	flow	flow	flow	flow	flow	flow	flow	EB16	KEB19	CT35	KOST	EB14	MA3A	CT118	CT51	CT60
H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	H	M	M	M	M	M	
46.70	45.68	47.80	48.14	48.85	49.14	49.79	50.10	46.66	48.64	48.98	52.07	52.63	51.47	51.37	48.84	50.74	50.83	48.99	51.03	49.34	51.38	
3.05	3.09	3.15	2.62	2.42	2.70	2.41	2.42	3.10	2.46	2.51	2.29	2.43	2.05	1.83	2.58	2.13	2.22	2.55	2.17	2.45	2.23	
17.01	16.07	17.55	15.43	15.45	17.10	15.84	16.67	16.45	17.40	17.60	15.97	17.37	16.8	16.13	17.25	17.97	16.39	16.83	17.32	17.14	17.40	
10.87	13.04	12.30	13.65	11.26	11.89	12.00	11.62	12.83	10.73	10.52	11.12	9.50	10.14	9.44	11.07	9.87	8.99	11.18	9.39	10.69	9.80	
0.16	0.19	0.15	0.21	0.16	0.18	0.17	0.15	0.16	0.22	0.19	0.17	0.12	0.14	0.17	0.16	0.20	0.11	0.16	0.22	0.17	0.13	
4.24	5.28	5.29	5.99	5.89	4.46	5.52	4.41	4.90	4.41	4.37	5.18	3.36	4.27	4.63	4.69	2.84	2.96	4.21	3.91	3.59	4.20	
8.99	7.95	7.08	7.95	8.07	8.38	7.80	7.56	7.43	8.27	8.20	7.33	8.19	7.77	7.07	6.95	7.21	7.86	6.93	7.20	6.73	5.65	
3.44	3.67	3.72	4.04	3.89	4.00	3.96	4.01	4.26	4.74	4.62	4.32	4.71	4.68	4.37	4.66	4.51	4.71	5.47	4.76	5.58	4.99	
1.84	2.09	1.59	1.99	1.42	1.43	1.45	1.41	2.00	1.77	1.78	1.76	1.50	1.77	1.93	2.48	1.79	1.80	2.48	2.32	2.56	2.31	
0.81	0.79	0.53	0.70	0.56	0.64	0.48	0.48	0.80	0.71	0.75	0.50	0.46	0.64	0.63	0.76	0.92	0.48	0.83	0.67	0.79	0.66	
2.88	1.98	0.77	-0.25	1.72	-0.01	0.49	1.06	1.02	0.63	0.46	0.13	-0.36	-0.09	1.76	0.57	1.96	3.32	-0.06	2.09	0.20	0.70	
99.99	99.83	99.93	100.47	99.69	99.91	99.91	99.89	99.61	99.98	99.98	100.84	99.91	99.64	99.33	100.01	100.14	99.67	99.57	100.00	99.56	99.58	
40.05	40.63	41.68	42.00	42.23	42.22	42.78	43.21	44.13	45.62	45.78	47.08	49.00	49.12	49.99	49.32	50.10	51.44	52.56	53.37	54.08	54.57	
174.6	205	184.2	159	183	162.7	203	159.3	179	144.9	142.1	158.8	168	142	112	140	97.5	160	159	111	133	131	122.8
20.9	46	31.46	119	153	45.05	155	48.08	28	51.31	49.33	135.1	51.83	110	110.7	20.52	8.99	46	24	24.3	32	37	47.15
25.97	33.8	37.38	35.9	32.8	30.55	39.8	31.78	32.8	28.03	24.87	32.61	22.77	24.4	23.96	28.01	19.4	20.4	25.9	19.9	23.6	23.9	
17.12	57.00	48.36	88.8	96.00	37.9	106.00	49.83	38.00	35.32	30.92	98.14	45.00	61.00	68.79	32.43	9.65	45.00	29.00	11.5	35.00	44.00	
23.09	49.52	27.93	62.3	51.4	38.53	40.3	38.15	43.14	27.95	27.09	41.34	66.21	31.39	38.35	29.29	16.84	57.11	25.44	19.7	24.41	47.48	
21.99	25.24	23.03	21.4	24.36	24.70	26.30	24.05	24.52	24.22	24.59	24.07	25.31	26.32	25.08	25.20	26.7	26.00	25.26	26.70	27.41	24.59	
56.27	54.00	30.13	64.7	34.00	30.59	38.10	30.87	52.00	41.32	38.46	33.48	37.42	42.00	50.89	59.72	44.00	55.00	65.00	65.40	71.00	73.65	
989.1	1188.0	904.5	774.0	562.0	598.9	569.0	513.4	1027.0	1077.0	1063.0	453.2	528.0	644.0	616.3	1125.0	937.4	526.0	1075.0	963.0	1170.0	968.0	
28.94	35.80	28.37	30.60	26.8	32.63	32.5	27.25	33.7	30.93	30.82	27.99	27.33	50.1	31.61	33.7	37.08	28.5	32.7	35.4	35.3	31.2	
335.5	437.0	300.3	383.0	277.0	252.0	308.0	269.8	393.0	303.1	306.9	365.3	317.0	346.0	396.7	535.8	312.2	356.0	466.0	452.0	522.0	449.0	
64.39	100.48	63.64	79.9	52.31	50.38	56.9	47.37	86.33	82.14	83.61	57.19	50.71	66.76	69.29	96.4	79.6	59.42	101.56	102	109.04	85.13	
47.22	655.0	472.4	449.0	414.0	412.7	454.0	367.7	591.0	710.6	710.1	450.9	419.46	477.0	464.5	663.9	913.1	473.0	680.0	853.0	740.0	793.0	
7.17	9.00	6.58	8.19	6.24	5.65	7.10	6.26	8.16	6.57	6.63	7.67	7.00	7.86	8.18	10.47	6.87	7.59	9.46	9.92	10.71	9.55	
4.73	7.06	4.62	6.39	3.76	3.81	3.94	3.63	6.23	5.74	5.85	4.18	3.78	4.76	4.99	6.82	5.52	4.22	7.32	7.4	7.85	7.11	
3.35	3.98	2.98	4.24	1.52	2.23	2.42	2.15	3.51	4.01	4.18	3.09	2.15	3.19	3.98	3.92	4.61	2.86	3.87	6.22	4.46	4.35	
5.53	7.27	4.85	9.71	4.26	4.07	5.16	4.86	7.17	7.47	7.58	5.74	4.51	6.28	7.28	6.85	8.04	5.52	7.95	10.30	9.00	8.40	
1.45	1.88	1.42	2.63	1.3	0.95	1.41	1.30	2.12	2.15	1.84	1.12	0.91	0.91	2.12	1.80	1.84	1.86	2.16	2.92	2.64	2.93	
52.65	77.67	47.11	53.00	40.48	43.65	46.6	38.37	68.55	74.48	75.38	42.78	38.36	61.92	51.44	72.83	75.74	42.87	80.96	79.40	82.55	72.54	
111.70	158.00	91.80	102.00	83.00	82.89	86.00	75.56	138.00	144.00	146.10	85.38	74.39	101.00	104.1	146.4	147.9	83.71	150.00	152.00	131.00	135.10	
13.38	18.25	11.22	11.70	9.59	10.55	10.50	9.13	15.33	16.12	16.30	9.77	8.08	12.65	11.83	16.81	16.87	9.34	17.38	18.00	18.26	14.83	
53.13	69.00	44.40	44.99	39.70	42.88	43.90	36.96	59.58	59.92	60.77	37.44	34.00	51.25	46.27	63.92	65.12	36.89	65.09	71.70	70.25	58.69	
10.17	13.32	8.87	9.06	8.53	9.40	9.11	8.06	11.07	10.75	10.98	7.89	7.32	10.33	9.28	11.90	12.14	8.73	11.17	13.3	12.64	11.46	
3.14	3.99	3.01	2.83	2.81	3.24	3.18	2.74	3.51	3.87	3.95	2.58	2.50	3.42	2.94	3.73	4.82	2.52	3.47	3.78	3.03	5.12	
8.21	11.28	7.52	7.78	7.13	8.72	8.32	7.44	9.12	8.89	9.04	7.20	7.20	9.42	7.97	9.47	10.36	6.71	9.34	10.20	9.99	9.00	
1.13	1.49	1.09	1.13	1.03	1.24	1.09	1.07	1.26	1.22	1.25	1.05	1.05	1.14	1.15	1.32	1.45	1.07	1.27	1.48	1.39	1.22	
6.01	7.12	5.82	6.18	5.74	6.66	6.20	5.82	6.54	6.45	6.49	5.90	5.33	7.84	6.35	6.86	7.64	5.71	6.55	7.30	7.33	6.24	
1.01	1.25	1.03	1.08	1.16	1.13	1.02	1.24	1.11	1.11	1.02	1.03	1.64	1.11	1.17	1.33	1.13	1.22	1.34	1.40	1.15	1.05	
2.66	3.30	2.63	2.88	2.27	3.04	2.66	2.54	2.66	2.79	2.86	2.64	2.68	2.88	2.98	3.36	2.45	2.61	3.42	3.02	2.59	2.71	
0.36	0.4	0.35	0.41	0.31	0.41	0.41	0.33	0.29	0.37	0.37	0.37	0.34	0.51	0.39	0.40	0.45	0.38	0.45	0.34	0.38	0.38	
2.25	2.64	2.20	2.60	1.93	2.47	2.23	2.06	2.24	2.22	2.26	2.28	1.92	2.03	2.54	2.49	2.75	2.29	2.42	2.05	2.41	2.40	

Pre-Manengouba lavas														
Baré	Nzoh substratum	NW Marjo Cone 749	NW Bangem	Eastern old volcanic basement				North-western graben edges						
				Nkongsamba	Baressoumtou	Nkongsamba	S Nkongsamba	Bakossi	NW Bangem	W Bangem	Bakossi	NW Bangem	Ekomane	
	CT61 flow	NZ8 flow	CT42 flow	CT105 dome	CT30 flow	KBT5 flow	CT33 flow	PL5 flow	CT103 extrusion	CT14 extrusion	CT101 extrusion	CT107 extrusion	Essom pike	
M	M	M	Tr-Ph	H	H	M	M	Ph	Ph	Ph	Ph	Ph	Tr	
54.10	53.18	53.78	60.72	47.86	48.44	51.95	53.41	54.76	54.40	53.67	54.65			
1.65	1.58	1.86	1.08	2.85	2.33	1.96	1.95	0.20	0.18	0.19	0.40			
16.17	17.88	17.27	17.61	16.92	16.36	17.77	17.82	20.07	20.51	20.54	15.68			
9.49	8.32	8.47	3.75	11.94	13.85	9.37	8.81	4.33	3.37	3.34	3.36			
0.22	0.15	0.15	0.07	0.17	0.22	0.18	0.17	0.22	0.21	0.21	0.21			
1.78	2.59	3.35	1.47	5.14	3.23	3.22	3.06	0.31	0.23	0.38	0.42			
5.59	5.45	4.95	3.09	7.41	6.95	6.20	6.65	1.09	0.8	0.95	1.26			
5.22	5.66	5.09	6.72	4.14	4.42	4.76	5.41	9.69	10.14	8.67	4.77			
2.70	2.87	3.45	4.85	2.13	1.82	2.12	2.21	5.97	5.53	5.69	5.96			
0.57	0.71	0.55	0.31	0.82	1.04	0.57	0.64	0.07	0.07	0.06	0.08			
2.49	1.14	1.06	0.28	0.61	1.66	1.93	-0.13	4.12	4.46	6.14	2.20			
99.98	99.53	99.98	99.95	99.99	100.32	100.03	100.00	100.83	99.9	99.84	98.99			
62.21	62.61	62.66	82.50	44.83	47.97	54.29	56.96	86.94	89.56	90.65	91.70			
49.2	79	108.6	56.18	148	85.53	92.83	101	5.743	4.695	6.312	2.29			
10.85	12	20.04	23.05	23.76	15.93	38.18	37							
9.35	14.9	19.41	7.82	30.79	24.92	19.75	15.4	0.978	0.86	1.08	0.862			
6.84	15.00	25.25	14.12	36.92	15.11	23.61	23.00							
8.96	18.24	15.41	8.553	24.41	30.9	18.84	21.42							
25.9	26.71	25.47	25.67	24.25	23.00	25.32	25.99	40.85	39.54	40.18	29.31			
58.20	70	101.30	143.50	55.32	37.05	44.42	46.00	254.1	259.5	209.7	95.99			
61.30	1137.0	764.0	417.3	10690.0	9002.2	692.0	726.0	33.80	32.15	36.52	115.6			
41.43	33.20	30.00	50.39	33.69	33.91	35.50	34.70	26.20	26.54	48.24				
399.9	537.0	587.3	684.3	494.1	350.3	306.0	301.0	1001.0	1040.0	1013.0	831.3			
75.73	106.85	112.2	122.6	92.12	74.48	76.71	79.24	108.00	107.20	110.30	98.77			
1147.0	830.0	681.5	544.3	634.2	526.2	1739.0	2038.0	16.73	15.3	54.7	935.6			
3.02	1.04	1.221	14.23	9.93	7.6	6.83	6.24	16.24	16.55	16.15	16.95			
5.48	8.05	9.17	10.87	6.50	5.28	5.30	5.3	2.59	2.621	2.62	6.95			
6.02	5.00	5.55	8.12	3.46	3.41	3.34	4.71	29.61	29.5	29.49	13.60			
7.97	10.15	14.88	22.98	6.25	5.83	8.10	8.73	28.77	28.09	28.01	13.21			
1.89	3.09	4.03	6.38	1.64	1.59	1.65	2.45	9.06	8.60	8.98	3.22			
68.95	89.26	78.96	105.00	69.64	58.99	72.96	72.16	81.00	82.33	81.75	100.10			
140.80	168.00	145.6	136.8	142.00	121.20	134.7	143.00	102.4	101.00	105.20	200.40			
16.63	17.73	16.52	17.55	16.61	14.4	15.77	15.54	7.41	7.55	7.49	22.56			
66.44	65.20	580.6	61.67	63.77	56.94	58.84	59.30	19.12	19.30	19.49	81.18			
13.41	11.18	10.40	10.81	12.04	11.05	11.14	10.43	2.78	2.79	2.80	14.13			
5.14	3.53	2.94	2.51	3.75	3.52	5.19	5.04	0.73	0.75	0.74	2.62			
11.74	9.22	7.95	9.75	9.87	9.77	8.76	2.78	2.79	2.80	10.94				
1.56	1.28	1.16	1.44	1.35	1.29	1.36	1.20	0.48	0.47	0.47	1.66			
8.48	6.65	6.18	8.08	7.02	6.94	7.25	6.51	3.20	3.26	3.20	9.36			
1.53	1.28	1.06	1.53	1.18	1.19	1.27	1.21	0.76	0.76	0.75	1.72			
3.95	2.85	2.79	4.37	3.04	3.11	3.33	2.56	2.69	2.66	2.56	4.89			
0.55	0.26	0.40	0.62	0.39	0.42	0.44	0.28	0.46	0.47	0.46	0.72			
3.35	2.51	2.59	4.20	2.46	2.67	2.75	2.12	3.43	3.54	3.47	4.82			
0.49	0.34	0.39	0.66	0.35	0.40	0.40	0.23	0.54	0.56	0.54	0.76			