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1 **Erosion mode and history of Eastern Adamaoua landscapes (Cameroon):**

2 **Superimposed lateritic weathering of granites and basalts**

3
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25 **Abstract**

26 Landscapes of eastern Adamaoua highlands have been shaped by successive
27 weathering and erosion processes of Pan-African crystalline rocks and Neogene volcanics
28 cover. Basalts have outpoured through major inherited structural discontinuities mostly in
29 shallow incisions of lateritic pediplains previously shaped on the granitic basement. That has
30 resulted in formation of a singular composite lateritic weathering profile on basalt
31 superimposed to a truncated profile composed of mottled clays and saprolite on granite. The
32 composite profile studied here is little evolved, mostly kaolinised on granite while basalt is
33 weakly to moderately lateritised owing to differences in silica and iron oxide contents of the
34 two contrasted parent rocks. During lateritic weathering, Cu, Ni, and Co are enriched in
35 profile on granite but depleted on basalt, while Zr/Ti is relatively constant. Behavior and
36 fractionation of REE are comparable except higher Eu* and Ce* anomaly on granite profile
37 than on weathered basalt, owing to parent minerals differences, mostly feldspars in granite
38 versus plagioclase and Fe-Mg minerals in basalt. The contrast in Eu* is also linked to
39 differences in the Index Of Laterization (IOL) in weathered horizons of the two parent rocks.
40 Beyond quite classical litho-dependent geochemical differences in the composite profile,
41 persistence of per-humid climate and good drainage over Neogene have sustained rock-
42 weathering and local surface erosion processes upon volcanic outpours and their contact
43 surface with pediplains formed on Pan-African granitoids of Adamaoua highland.

44 **Keywords:** Lateritic weathering; Erosion; Granite; Basalt; Neogene; Cameroon.

45 **1. Introduction**

46 Lateritic landscape dynamics and formation of lateritic profiles on tectonically-stable
47 cratonic continental platforms across tropical belts have been primarily driven by climatic and
48 lithologic factors that constrained the amplitude of weathering, erosion and geomorphic
49 processes over Paleogene (Thomas, 1994; Tardy and Roquin, 1998; Colin et al., 2005;
50 Beauvais et al, 2008; Beauvais and Chardon, 2013; Beauvais et al., 2016; Chardon et al.,
51 2018; Vasconcelos and Carmo, 2018; Jean et al., 2020). West African lateritic paleo-
52 landscapes, whose relics are currently preserved for million years in West Africa (Beauvais
53 and Chardon, 2013) have formed under Paleocene – Eocene humid climates but afterward
54 evolved under post-Eocene drying climatic conditions across the West African platform (e.g.,
55 Chardon et al., 2018). Once swells like the Jos plateau plateau in Nigeria and the Adamaoua
56 highland in Cameroon have established under Paleocene - Eocene epirogenic uplift driven by
57 under-plating mantle activity (Burke, 2001), lateritic rock weathering process have operated
58 on the uplifted surfaces. Afterwards, lateritic paleo-landscapes evolved under long-lasting
59 humid climatic conditions (post-Eocene to late Neogene) that effectively prevailed upon these
60 uplifted platforms. Long-term preservation of lateritic paleosurfaces and regolith formed on
61 granitic basements depends on weathering and erosion processes intensity, which have been
62 differentially mostly amplified by major trajectories of climatic regimes and the possible
63 effects of eventual tectonics. For example, these factors combined together may have induced
64 deformation of previously formed paleo-landscapes and their drainage networks across and
65 around intra-cratonic swells (Burke and Gunnell, 2008; Grimaud et al., 2014; Chardon et al.,
66 2016).

67 The ancient lateritic landscapes (mainly pediplains) formed on the Pan-African
68 basement in Adamaoua mainly evolved under persistent humid climatic regimes during the
69 middle and late Cenozoic. Neogene basaltic flows outpoured over the pediplains through

70 major structural discontinuities, and their lateritic weathering has completed the edification of
71 composite profiles. Nguetnkam et al., (2020) described paleosols and saprolite on granite and
72 superimposed basalts, respectively, and interpreted the current lateritic profile edifice as the
73 result of local relief inversion of a previous valley on granite filled by late Neogene basalts.
74 Eventual tectonic effect of basalt outpourings (among other volcanics) on landscape incision
75 remains however a matter of debate that is out of the scope of this paper. Here, we document
76 the history and erosion mode of Eastern Adamaoua landscape by describing in details the
77 formation of such a composite lateritic profile on the basis of major petro-geochemical
78 evolution paths across that profile, complemented by regional scale field observations on
79 geomorphological surfaces and regolith types on granite and basalt in and around the studied
80 profile. We considered the major influence of long-lasting per-humid climatic conditions on
81 the geochemical differentiation and elements fractionation across the lateritic profiles formed
82 on the different lithologies and upon the landscape erosion pattern of eastern Adamaoua
83 highland. The known ages (~9 to ~11 Ma; see Marzoli et al., 1999) of basaltic flows over
84 lateritic pediplains previously formed on granite basement impose a relative chronology of
85 weathering and landscape erosion. Our study opens perspectives to larger scale analysis of
86 volcanically-driven regolith geomorphological markers that seal the minimum age of
87 underneath lateritic pediplains on Adamaoua highlands.

88

89 **2. Major geological and geomorphological features of Eastern Adamaoua**

90 The granitoid basement of the Adamaoua plateau belongs to the Pan-African orogenic
91 belt of Central Africa ($^{207}\text{Pb}/^{206}\text{Pb}$ zircon ages of ~ 500-600 Ma, Ganwa et al., 2011). Pulses
92 of volcanic activities with evidences of mantle sources (lherzolites, Girod et al., 1984)
93 resulted in establishment of strato-volcanos (~ 400 m, Marzoli et al., 2000) upon previously-
94 formed lateritic sequences on granitoids, in eastern Adamaoua highland (Figs. 1a-b). Basalts

95 outpoured through structural discontinuities (opened faults and fractures) inherited from post-
96 orogenic distensile tectonics that affected the Pan-African basement of Adamaoua (Deruelle
97 et al., 1991). Detailed chronological and petrological studies revealed successive stages of
98 volcanic activities (Marzoli et al., 1999, 2000; Delor et al., 2021). Voluminous stratoid
99 alkaline basalts and basanites at c. 11 Ma, are then covered, from 11 Ma to 9 Ma, by silicic
100 magmas extrusions mainly nepheline-rich trachytes (Marzoli et al., 1999) with spots of
101 rhyolites and phonolites (Lasserre, 1961) at Tchabal Nghana (Fig. 1a). A last stage is
102 represented by minor basaltic flows and pyroclastic deposits dating from Quaternary (Kagou
103 Ndongmo et al., 2010). The wide age range from Miocene to Quaternary is suggestive of
104 multiple magmatic hot-spots operating beneath the Cameroon Volcanic line (Marzoli et al.,
105 1999; 2000).

106 Low-relief lateritic landscapes are marked by a NW sloping regional composite
107 surface on granitoids and volcanics (Fig. 1b). On syn-tectonic granites, lateritic pediments
108 form kilometers wide rolling pediplain between c. 1200 m a.s.l. to c. 1420 m a.s.l (Fig. 1b),
109 which are interrupted by c. 40 m height hills of poorly weathered recent basalts/basanites
110 (Fig. 2a). Lateritic duricrusts formed on pediments at c. 1200 m altitude show a composite
111 assemblage of nodular and massive ferricretes (Fig. 2b). At higher altitudes, hillsides of
112 truncated weathering profiles on pediments are covered by saprolites or sandy mottled clays.

113 Scarped erosion slopes mark major lithological unconformity between the upper
114 pediplain on syn-tectonic granites and the lower pediment surface on migmatites and gneiss
115 (Fig. 1b). This is linked to a regional extension of a faulting system N70°E that established on
116 the Adamaoua highland as a result of Albian-Cenomanian extensive tectonic (Allix et al.,
117 1984) with major lithological control (see Fig. 1). Below the scarped slope at c. 1100 m a.s.l.
118 (Fig. 1b), piedmont surfaces are covered by ferricrete (Figs. 2c-d).

119 In contrast to landscape on granitoids, landsurfaces on mid-Miocene basalts are
120 marked by a succession of smoothed hills covered by consolidated ferricretes/bauxites, that
121 are dismantled mostly on the edges of eroded plateaus (Fig. 2e), which the incision led to the
122 formation of a lower and younger pediment surface (Fig. 2f).

123

124 **3. Methodological approach**

125 Field geomorphological observations at regional scale (Fig. 1a) allowed to
126 characterize lateritic landsurfaces deriving from lateritic weathering of granitoids and basalts,
127 and landscape dissection (Fig. 1b). This detailed geomorphic characterization was undertaken
128 along a NW-SE prospect in area exposing a patchwork of multiple weathered volcanic covers
129 and surfaces of lateritic pediplains formed on granite. Field stations (Fig. 1a) were chosen to
130 also analyze the broader ranges of altitudes in the studied area (Fig. 1b) including a major
131 structural discontinuity of the Adamaoua that may constrain the lateritic surfaces distribution.
132 At a given field station, elevations and petrographic descriptions of preserved
133 regolith/duricrusts on granite or basalts were recorded and linked to specific landscape
134 morphology.

135 Based on a detailed geological map (Lasserre, 1961), field survey allowed to
136 determine outcrops of composite weathering profiles, that are arranged preferably around
137 geological contacts between crystalline basement and overlying lavas flows, e.g. Mangoli (see
138 Nguetnkam et al., 2020, and this study, Fig. 1). A road trench exposing 35° NW-dipping
139 structures permitted to describe the weathering profile MEI01 and its different horizons
140 formed on granite and basalt (Fig. 3a). The composite weathering profile exemplified regional
141 scale regolith formed on low-reliefs lateritic pediplains and erosional slopes on granitoids,
142 which have been then covered by mid- to late Miocene volcanics (basalts and/or andesites)

143 before renewed weathering and laterization under propitious climatic conditions over the late
144 Neogene.

145 Eleven samples including the two parent rocks (granite and basalt) were collected in
146 the different horizons of the weathering profile section (Fig. 3a). Weathered samples were
147 described according to reference nomenclature of Nahon (1991) and Tardy (1997), while their
148 dominant hue was estimated using codes from the Munsell color chart (Mc).

149 Samples were prepared and analyzed by the ALS Laboratory Group SL, Spain.
150 Samples were crushed to a sieved size of 2 mm that underwent further pulverization such that
151 more than 85% of grounded sample be sieved to 75 μm . Prior to 4 acid dissolution and ICP-
152 MS analysis, the lithium borate fusion was applied to samples, that is suited for quantitative
153 analyze of whole rock elements. The quality control here is based on a number of blanks,
154 reference materials (standards) and duplicates that are analyzed along with the samples. The
155 ICPMS (Inductively coupled plasma-Mass spectrometry) method was used for analyzing a
156 combination of Major (wt.%), Trace and Rare Earth elements in ppm (ME-MS81TM + whole
157 rock package ME-ICP06; www.alsglobal.com). The detection limits of each element are
158 given in the table 1 caption, table 2 and 3.

159 The geochemical Index Of Laterization, IOL, was also calculated for better
160 understanding and comparing lateritic weathering processes intensity in each section of the
161 composite profile. The IOL considers major elements, Al, Si and Fe, involved in the lateritic
162 processes such as:

163

$$164 \quad \text{IOL} = 100 \times \left[\frac{(\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3)}{(\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3)} \right] \quad (1)$$

165

166 The IOL values were then reported on a scale alongside a ternary diagram (SiO_2 -
167 Al_2O_3 - Fe_2O_3), which allow to distinguishing different laterization grades (Schellmann, 1994;
168 see also Babechuk et al., 2014).

169

170 **4. Results**

171 4.1. Petrological differentiations across the composite profile

172 The profile is composed of weathering horizons formed on granite and overlying
173 basalt defining two sections separated by an unconformity marking a rippled contact (Fig. 3a),
174 which dips ca. 35° roughly parallel to surface slope gradient toward the local valley incision
175 to the NW. From the bottom to the top of the profile on granite, a ca. 4 m thick nodular
176 horizon M1g is overlaid by a 3.3 m thick mottled clay M2g on granite, while a 2.4 m thick
177 mottled clay M1b topped by 2.3 m thick pebbly horizon compose the profile on basalt (Fig.
178 3).

179 Granite (Fig. 4a) is composed of quartz, feldspars, amphiboles and biotites. Blocks of
180 granite also outcrop in river beds and are widespread in adjacent lowlands where lateritic
181 regolith has been stripped. At the bottom of the profile, the nodular horizon (M1g) is made up
182 of a brown-reddish clay-ferruginous matrix (Mc: 2.5 YR 4/8) embedding few nodules with
183 some preserved centimeter-sized whitish saprolitic relics (Fig. 4b). In higher part of this
184 horizon (Fig. 3b), numerous pluri-centimeter sized dark-red nodules (Mc: 10R 3/6) are
185 embedded in a reddish (Mc: 2.5 YR 3/5) friable internodular matrix (Fig. 4c); the horizon is
186 limited upward by a centimeter-sized dark brown crusting (Fig. 3a-b). The overlying
187 yellowish-red (Mc: 5YR 4/5) mottled clays (M2g) are formed in-situ. The upper part is made
188 up of a yellowish-red to yellow clay-ferruginous matrix (Mc: 7.5 YR 7/6) studded with quartz
189 grains (Fig. 4d). The lower part of M2g shows the original structure of the fresh granite rock
190 crossed by a network of fractures marked by iron crystallizations coating (Figs. 3a-b and 4e).

191 Basalt coarse structure is preserved in the upper section of the weathering profile with
192 a columnar-jointed vertical network in the mottled clays horizon (Figs. 3d). Basalt is dark
193 grey massive and microcrystalline (Fig. 5a), with some phenocrysts of olivines and pyroxenes
194 observed under a magnifying glass. The base of the profile on basalt is made up of a
195 yellowish (Mc: 7.5 YR 7/6) mottled clay horizon (M1b), which shows a sharp transition with
196 the underlying horizons on granite (Fig. 3c). This horizon is massive and made up of
197 undifferentiated yellowish clay studded with preserved structures of micrometric inherited
198 primary minerals, and crossed by centimeter sized voids filled with a dark brown (Mc: 7.5 YR
199 5/5) loose fine earth (Fig. 5b). The basaltic structure is progressively indistinct in the pebbly
200 horizon M2b composed of 70% pebbles and 30 % fine earth (Fig. 5c).

201

202 4.2. Major and trace elements across the composite profile

203 Graphical distributions of major elements and IOL values are showed in figures 6 (see
204 also analyses in Tab. 1). Data analysis highlights decreasing SiO_2 content and increasing
205 contents of Fe_2O_3 and Al_2O_3 relative to the respective parent rocks (Fig. 6). The maximum
206 depletion of SiO_2 and element enrichment of Fe_2O_3 occur at the top of the nodular horizon
207 (M1g) on granite (Figs. 6 and 7a).

208 Laterization index IOL progressively increases from parent rocks to kaolinized
209 weathering horizons on granite, and to weakly and moderately lateritised horizons on basalt
210 (Fig. 6; see also Tab. 1).

211 Trace elements behavior relative to parent rocks are given in the figure 7 (see also
212 Tab. 2) and their relations to each other and major elements in figures 8. Ba, Rb, Sr and Zr are
213 the most abundant trace elements in the granite with up to 1035 ppm for Ba (Tab. 2); trace
214 elements in weathering horizons are further enriched relative to the granite except Sr, Rb, Ba,
215 Y and Zn, which are depleted (Fig. 7a). Nb, Zr, Ga, Cu, Ni, Co, Cr, V, Sc, Th, Hf, U and Ta

216 contents increase from the fresh granite to the top of the lower section of the profile (Fig. 7a;
217 Tab. 2) and vary together in the weathering horizons (e.g., $r^2_{Cr-Th}=0.81$; Fig. 8a-b). Trace
218 elements are also IOL dependent with a significant enrichment with increasing laterization
219 (e.g., $r^2_{IOL-Th}=0.98$; Fig. 8c-d). Their distribution in the section is linked to major oxides like
220 TiO_2 , Al_2O_3 , and Fe_2O_3 to some extent (e.g., $r^2_{Ni-Al_2O_3}=0.90$; Fig. 8e-h).

221 In the upper litho-section of the profile on basalt, Nb, Y, Sr, Ba, Zn, Ni, Co and Sc are
222 the most abundant trace elements in the parent basalt (Fig. 7b; Tab. 2). Two groups of trace
223 elements are further distinguished based on their content relative to the basalt. As in the lower
224 unit, the first group comprises high field strength elements (HFSE) Zr, Ga, Cr, V, Pb, Th, Hf,
225 U and Ta, which are known to be stable during lateritic weathering (Mordberg, 1996), and are
226 thus enriched relatively to their amount in the basalt (Fig. 7b; Fig. 8a-b). The second group
227 comprises depleted elements relative to basalt as Sr, Rb, Ba, Zn, Cu, Ni, Co and As. Enriched
228 trace elements in weathering horizons (\sum_{HFSE}) of this litho-section show increasing contents
229 from the mottled clay M1b to the surface pebbly horizon M2b (Tab. 2). In contrast, Nb, Ba,
230 Zn, Ni, Cu, Co, As, Sc, U and Ta contents decrease toward the surface. At the top of mottled
231 clay (M1b), Nb, Zr, Y, Ni, Ga, Cr, V, Sc, Pb, Th, Hf, U and Ta are relatively enriched (Fig.
232 7b and Tab. 2). In this profile section, trace elements behave differently, except some HFSE
233 (e.g., $r^2_{Hf-Ga}=0.90$; Fig. 8a-b). They instead vary with IOL and major elements like Al_2O_3 and
234 TiO_2 (e.g., $r^2_{Ni-TiO_2}=-0.87$; Fig. 8d-e) owing to kaolinite and anatase control, while negative
235 relation to Fe_2O_3 content (e.g., $r^2_{Ni-Fe_2O_3}=-0.63$; Fig. 8g-h) is suggestive of their release from
236 Fe-rich primary minerals (olivine, pyroxene) upon still ongoing basalt weathering. The
237 geochemical discrimination diagram Zr/Ti vs Nb/Y (Fig. 8i; based on Winchester and Floyd,
238 1977) further strengthens the parental lithological differences (Figs. 8b-d-f-g). Basalt is richer
239 in Ti, Zr, Nb and Y than granite, and the behaviour of these elements is quite contrasted in the

240 two weathered litho-sections (Tabs. 1 and 2) that portrays maintained geochemical signatures
241 during sequential profile maturation.

242

243 4.3. REE behavior across the composite profile

244 REE contents vary from 0.13 ppm to 516 ppm in the composite profile (Tab. 3) with
245 maximum abundances for LREE. In the lower section, LREE and HREE are mostly depleted
246 in the nodular horizon M1g while enriched in the yellowish-red mottled clays M2g relative to
247 the granite, except La, Ce and Tb that are depleted in the overall lower unit of the profile (Fig.
248 9a; Tab. 3). In the upper section, LREE namely La, Pr, Ce and Nd are enriched while Sm, Eu,
249 Gd and LREE show contrasted behavior and are either depleted or enriched relative to the
250 basalt (Fig. 9b; Tab. 3). REE vertical distribution displays a slight increase along the profile
251 section with apparent enrichments at the top of the nodular duricrust M1g and the top of the
252 yellowish mottled clay (Tab. 3).

253 The C1 chondrite normalized REE spectra (Mc Donough and Sun, 1995) for granite
254 and weathered samples are similar and evidence important HREE fractionation relative to
255 LREE along the lower section of the profile (Fig. 9c). The normalization pattern further
256 highlights Ce* and Eu* anomalies (Fig. 9c; Tab. 3). Indeed, the granite and the yellowish-red
257 mottled clay M2g show Ce/Ce* values of ~1 (Tab. 3) indicating no depletion/enrichment
258 relative to La and Pr (Fig. 9c). Lowest Ce/Ce* values with minimum of 0.41 in the nodular
259 horizon M1g (Tab. 3) further imply negative Ce anomaly in this horizon (Fig. 9c).
260 Normalization patterns also highlight highest Ce/Ce* for the basalts (0.95) while decreasing
261 values in the yellowish mottled clay M1b and the pebbly surface horizon M2b to 0.65 (Tab. 3)
262 are also significant of reducing conditions upon basalt weathering (Fig. 9d).

263 The C1 chondrite normalized Eu/Eu* further display negative anomalies across the
264 whole profile (Fig. 9c-d). Granite (Eu/Eu*=0.53) and basalt (Eu/Eu*=0.91) anomalies (Tab.

265 3) first indicate a depleted Eu granite relative to Eu- and plagioclase rich basalt. Eu/Eu^*
266 variations across the profile further show lower values in the granite section (~ 0.6) with well-
267 marked anomalies (Fig. 9c), while the basalt litho-section has higher values and lower
268 anomalies in (~ 0.8 ; Fig. 9d). Eu/Eu^* increases with IOL in the granite section of the profile
269 (Fig. 10a) with no clear trend but higher IOL and Eu/Eu^* in the basalt section (see also Tab. 1
270 and Fig. 6). The overall $\sum REE$ dependence on IOL is also better expressed in the lower part
271 of the litho-section on granite ($r^2_{\sum REE-IOL} = 0.96$) than in the higher litho-section on basalt (Fig.
272 10b).

273 Highest La/Y values occur in the nodular horizon M1g, while the lowest values are
274 recorded upper in the yellowish-red mottled clay M2g in the lower section; then La/Y
275 decreases upward in the upper section of the profile (Tab. 3). Ratio La/Y evolves like $\sum REE$
276 in the higher and the lower section of the profile ($r^2_{\sum REE-La/Y} = 0.97$ vs. 0.87), while $(La/Yb)_N$
277 varies less with $\sum REE$ ($r^2 = 0.66$; Fig. 10c). The $(Gd/Yb)_N$ ratio show lowest values (2-4) in the
278 nodular horizon, the yellowish red mottled clay and the surface pebbly horizon (Tab. 3). Its
279 highest value 10.33 along with highest $(La/Yb)_N$ in yellowish mottled clays M1b of the upper
280 section on basalt (Fig. 10d) highlight LREE enrichment relative to HREE in early stage of
281 lateritic weathering. Eu/Eu^* vs $(Gd/Yb)_N$ differentiates end terms fractionation between the
282 lower litho-section on granite and the upper litho-section on basalt (Fig. 10e), while $(La/Yb)_N$
283 and Ce/Ce^* differently evolve (Fig. 10f).

284 In the lower litho-section on granite, $\sum REE$ are highly related to Fe_2O_3 and P_2O_5
285 amounts ($r^2 = 0.97$, and $r^2 = 0.95$, respectively) indicating iron oxides and phosphates as
286 potential hosts minerals (Braun et al., 1993). Inversely, their opposite behavior from SiO_2 and
287 Al_2O_3 ($r^2 = -0.94$, and $r^2 = -0.74$, respectively) is indicative of their release during dissolution of
288 primary Si-Al minerals without secondary trapping by kaolinite. However, in the upper
289 section on basalt, $\sum REE$ variations with SiO_2 , Al_2O_3 , TiO_2 , MnO_2 and P_2O_5 ($0.53 < r^2 < 0.99$)

290 indicate kaolinite, iron oxides, ilmenite and phosphates as potential carriers. But, their
291 behavior different from FeO₂ ($r^2=-0.88$) is instead indicative of ongoing REE release from
292 residual ferruginous primary minerals (olivines and pyroxenes) without trapping by secondary
293 iron oxy-hydroxides given the low IOL calculated in the upper section of the profile (see Tab.
294 1; and Fig. 6).

295

296 **5. Discussion**

297 5.1. Differentiated geochemical weathering across the composite lateritic weathering profile

298 Petro-geochemical differentiations across the composite profile reflect different in-situ
299 weathering paths owing to the different lithologies and age of each profile litho-section that
300 control the distribution of major elements. These differentiations resulted in a Si-rich lower
301 section on granite while Fe-rich horizons developed on basalt. The lower litho-section on
302 granite is mainly characterized by processes of kaolinization to weak laterization (see Fig. 6),
303 which have preserved parent rock structure in the uppermost mottled clays horizon, with
304 obvious ferruginizations in maintained fractures (Figs. 4e). Heating effect of basalt
305 outpouring ~ 9 Myr. ago on clay rich mottled clays may have further exaggerated the pre-
306 existing fractures in a “shrinkage slots” pattern, that favored to Fe-oxyhydroxides
307 crystallizations/coating (Fig. 4e), and/or transfers and nodular segregations of iron in the
308 underlying granitic litho-section during late Neogene weathering (Fig. 11). The lowermost
309 nodular horizon M1g of the granite litho-section therefore results from relative downward
310 enrichment of Fe (Figs. 6 and 7a) that partially deleted the original granite structure (see Figs.
311 4b). At the top of this nodular horizon, formation of centimeter sized ferruginous concretions
312 and nodules (Figs. 4c) in a loose inter-nodular matrix along with increasing Fe₂O₃ content and
313 IOL (Fig. 6; Fig. 7a) emphasize mobilization and further segregation of iron under contrasted

314 conditions in an area of water table fluctuation (see Beauvais, 1999). In such conditions,
315 formation of nodules results from redox-controlled dissolution/precipitation processes of iron,
316 which preferentially accumulated in kaolinite-rich domains of mottled clays (Tardy and
317 Nahon, 1985; Ambrosi and Nahon, 1986a; Muller and Bocquier, 1986; Tardy, 1997;
318 Beauvais, 1999, 2009; Löhr et al., 2013) to ultimately form ferruginous nodules and/or
319 nodular ferricrete.

320 Trace elements display contrasted behaviors; Cu, Ni, Co are enriched in weathering
321 horizons on granite while depleted in horizons on basalt. Trace elements composition also
322 reveals increasing contents of Nb, Zr, Ga, Ni, Co, Sr, and Rb upward, which vary with major
323 elements in the lower litho-section on granite (Tab. 2). In contrast, these elements decrease
324 from the bottom to the top of the upper litho-section of the profile on basalt (Tab. 2), after
325 their release from relic pyroxene and olivine. Trace elements behavior to major elements
326 ($0.56 \leq r^2 \leq 0.71$) in the basalt litho-section portrays their enrichment in the weathering
327 profiles by trapping in iron oxides, anatase and possibly P-bearing minerals (Ambrosi and
328 Nahon, 1986b; Mordberg, 1996).

329 Fractionation differences of LREE (La and Ce) vs HREE (Yb) and Ce* anomaly
330 depend on varying redox conditions across the composite profile (Braun et al., 1993;
331 Boulangé and Colin, 1994; see also Brown and Helmke, 2003; Su et al., 2017), e.g., as
332 illustrated in figure 4e. The variation of $(La/Yb)_N$ vs. $\sum REE$ (Fig. 10c) corroborates
333 differential REE fractionation with laterization grade (different IOL) and possibly pH
334 variations in the two litho-sections (Zarasvandi et al., 2012). Negative Ce/Ce* anomaly is
335 stronger in the granite litho-section than on basalt (Figs. 9b-c) reflecting differences of redox
336 conditions, (Braun et al., 1993; Beauvais, 1999; Momo Nouazi et al, 2019). Ce depletion
337 relative to La and Pr generally depends on reducing conditions (see Compton et al., 2003;
338 Nyakairu and Koeberl, 2001). The Eu/Eu* negative anomaly is also stronger in the granite

339 litho-section than on basalt (Fig. 9c-d) that emphasizes the lithological dependence of less
340 weathered horizons on relatively young basalt compared to granite. Higher Eu/Eu* anomaly
341 and relatively higher IOL in the basalt litho-section (Fig. 6) depend on residual Fe-Mg
342 minerals in the early-stage weathering but moderate laterization process of basalt (Tab. 1 and
343 Fig. 6).

344 The last stage of profile development after the emplacement of the ~ 9 Myr. old
345 basalts upon weathered granitic regolith was still sustained by per-humid climatic conditions
346 on Adamaoua that also prevailed more widely across the continental intertropical belt during
347 the Mid-Miocene climatic optimum (e.g., Beauvais et al., 2008; Jean et al., 2020).

348

349 **5.2. Landscape erosion signatures from the composite lateritic weathering profile**

350 The unconformity between the weathered basaltic cover and the mottled clay horizon
351 formed in situ on granite (Fig. 3a) marks the erosion surface upon which the basalts outpoured
352 ~ 9 Ma ago. Around Mayo-Bali (Fig. 1), this erosion surface exposes deeper weathering
353 horizons, like mottled clays, after truncation of the top ferricrete (Fig. 11a-b) although
354 remnants may be preserved at lower altitudes (~1200 m) over syn-tectonic granitoids (Fig. 2a-
355 d). The general rolling morphology of the pediplain formed on granite (Fig. 1b) does not
356 show younger stepped reliefs that suggests slow landscape incision and erosion limited to the
357 duricrusted top of lateritic profiles (see Chardon et al., 2018). Under persistent per-humid
358 climatic conditions, erosion of ferricrete-capped glacia/pediment apparently prevailed over
359 rivers down-cutting (Grandin, 1976). That resulted in a low relief saprolite/mottled clay-
360 mantled erosion surface (Fig. 11b) in between shallow incised valleys, in which Neogene
361 basalts have spilled out covered the downslope eroded portions of the lateritic pediplain
362 previously formed on granite (Fig. 11c).

363 Mid- to late Miocene volcanics outpourings through pre-existing structurally
364 controlled discontinuities across the granitic basement resulted in limited local incision of
365 previous lateritic pediplains formed on granites. Note also that iron-poor Pan-African
366 basement of Adamaoua limited regolith duricrusting and strength allowing lateritic profiles
367 truncation on pediplains. After ~ 9 Ma, basalts/andesites weathered and their lateritic regolith
368 evolved with marked hillside incisions into a younger surface (Figs. 1b and 2e-f). Late
369 morphogenetic processes related to weathering/duricrusting on basalts also included late
370 Neogene lateritic weathering previously formed profiles on the granitic basement (Fig. 11d).
371 Landscape topography has been only locally rejuvenated under persistent per-humid climatic
372 conditions and sustained drainage that have however mostly enhanced weathering and
373 geochemical differentiations in the composite profile (Fig. 11d). In Eastern Adamaoua,
374 rugged erosional terrains with average slope gradient of ~4 to 5 % between wide domains of
375 pediplains (Fig. 1b) also portray hillslope erosion that preferentially occurred on inherited
376 litho-structural discontinuities (see also Sawadogo et al., 2020). Landscape physical
377 rejuvenation was also previously observed in western highlands of Cameroon (Momo Nouazi
378 et al., 2019) on Mid-Miocene basalts and trachytes, and possibly occurred during a period
379 (i.e., Pliocene) of mechanical (clastic) erosion (Tchouatcha et al., 2010).

380

381 **6. Conclusion**

382 Upon Eastern Adamoua highland, Neogene basalts outpourings through inherited
383 structural discontinuities have locally spread in shallow incisions of low-relief lateritic
384 pediplains previously established upon granitic basement. This resulted in the formation of
385 superimposed composite weathering profiles on granite and basalt. Though the studied profile
386 is moderately lateritised, the two sections on granite and basalt are differentiated by their
387 variable index of laterization (IOL), and specific behaviors of some trace and REE elements

388 relative to their respective amounts in each parent rock. Transition elements Cu, Ni and Co
389 are more enriched in the weathering section on granite than on basalt. Owing to contrasted
390 amounts of heavy minerals in the two parent rocks, Zr, Ti, Nb and Y also shows a contrasted
391 pattern, with decreasing (Zr/Ti) and increasing (Nb/Y) in the granite litho-section while
392 (Zr/Ti) remains constant in basalt litho-section. Differences of silicate minerals composition
393 of the two parent rocks also induced a differential weathering with negative Eu* anomaly
394 higher on granite section than on basalt. Eu* also increases with increasing IOL in the granite
395 litho-section, while REE further fractionated as indicated by the amplitude of co-variations of
396 $(La/Yb)_N$ and Ce*. After Neogene basalt outpourings on pediplain landscapes of Adamaoua
397 highland, persistent humid climatic conditions and efficient drainage have sustained rock
398 weathering processes with a noticeable differentiation and fractionation of trace and REE
399 elements across the composite lateritic profile.

400

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408

409

410

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551

552 **FIGURE CAPTIONS**

553 Figure. 1. a) Localization and geologic map of the study area. Structural, petrographic and
554 chronological data are adapted from Lasserre (1961); b) Geomorphological cross
555 section showing regolith landform distribution according to lithological variations in
556 Mayo-Bali area.

557 Figure. 2. Field illustration of lateritic landscape and regolith in the Eastern Adamaoua
558 plateau. a) Late Miocene volcanics morphology surrounded by alluvial plains and
559 granite-related pediments; b) Regolith structure of pediment with a nodular ferricrete
560 embedding massive and undifferentiated fragments; c) Footslope pediment below
561 erosional slope exposing bedrock (black arrow). d) Regolith structure of a footslope
562 pediment; e) Slope erosion of duricrusted lateritic regolith surface formed on basalt;
563 f) Regolith landscape on basalt with hillslope incision and formation of a younger
564 surface.

565 Figure. 3. a) Profile structure of the composite lateritic profile; b-d) Details of horizons
566 showing textural and lithological changes. The blue dotted line marks the lithological
567 unconformity between the lower and the upper part of the profile. b) transition
568 between the nodular horizon M1g and the overlying yellowish-red mottled clay M2g,
569 marked by the yellow dotted line in 3a; c) transition between the mottled clay M2g of
570 the lower section and the yellowish mottled clay M1b of the upper section; d)
571 transition between the yellowish mottled clay M1b and the surface gravelly horizon
572 M2b; evidences of prismatic basalts are shown. Numbered white squares are the
573 collected samples and correspond to samples ID in the tables.

574 Figure. 4. a) Granite sample of the Pan-African basement; b) lower part of the nodular
575 horizon with few nodules; c) Nodular horizon M1g with numerous nodules; d)
576 Undifferentiated structure of mottled clay M2g; e) Mottled clay M2g with preserved
577 granite structures.

578 Figure. 5. a) Aphyric basalt sample belonging to the early volcanics on the Adamaoua plateau.
579 b) Mottled clays M1b; c) Surface pebbly horizon M2b.

580 Figure. 6. Composition diagram Al-Si-Fe and index of laterization (IOL) along the composite
581 profile

582 Figure. 7. Granite and basalt normalized trace elements spider-diagrams of the different
583 horizons of the composite profile

584 Figure 8. Trace and major elements scattergrams. a) Hf vs Ga; b) Cr vs Th; c) IOL vs Cr; d)
585 IOL vs Th; e) TiO₂ vs Ni; f) Al₂O₃ vs Ni; g) Fe₂O₃ vs Ni; h) Fe₂O₃ vs Ga; i) Zr/Ti vs
586 Nb/Y

587 Figure. 9. a & b) Granite and basalt normalized REE spider-diagram of the different horizons
588 of the profile. c & d) Chondrite normalized REE spider-diagram of the different
589 horizons of the profile

590 Figure. 10. Geochemical diagrams of REE fractionation across the composite profile. a)
591 Eu/Eu* vs. IOL; b) \sum REE vs. IOL; c) \sum REE vs (La/Yb)_N; d) (La/Yb)_N vs (Gd/Yb)_N;
592 e) Eu/Eu* vs (Gd/Yb)_N; f) (La/Yb)_N vs. Ce/Ce*

593 Figure. 11. Schematic evolution of the lateritic weathering, and erosion of Eastern Adamaoua
594 landscape. a) Lateritic weathering profile of pediplains formed on the granitic
595 basement of Adamaoua highland. b) Erosion-truncated profile exposing mottled
596 clays at relatively high altitude (> 1200 m a.s.l.) at Mayo-Bali. c) Basaltic strata over

597 previously truncated profiles of pediplain formed on granite. d) Second stage of
598 landscape dynamics marked by lateritic weathering of both basalt and underlying
599 profile on granite.

600

601 TABLES CAPTION

602 Table 1. Major elements content (wt%) of each sample collected in the composite profile and
603 the fresh rocks. LOI = Lost of ignition; Detection limits: 0.01; (-) = Elements below
604 detection limits; IOL (%) = Index of Laterization; See figure 3a for the location of
605 each sample. Depths of fresh rocks samples are unknown.

606 Table 2. Trace elements content ($\mu\text{g/g}$) of each sample collected in the composite profile and
607 the fresh rocks. d.l. = Detection limits; (-) = Elements below detection limits.

608 Table 3. Rare earth elements content ($\mu\text{g/g}$) of each sample collected in the composite profile
609 and the fresh rocks. d.l. = Detection limit.

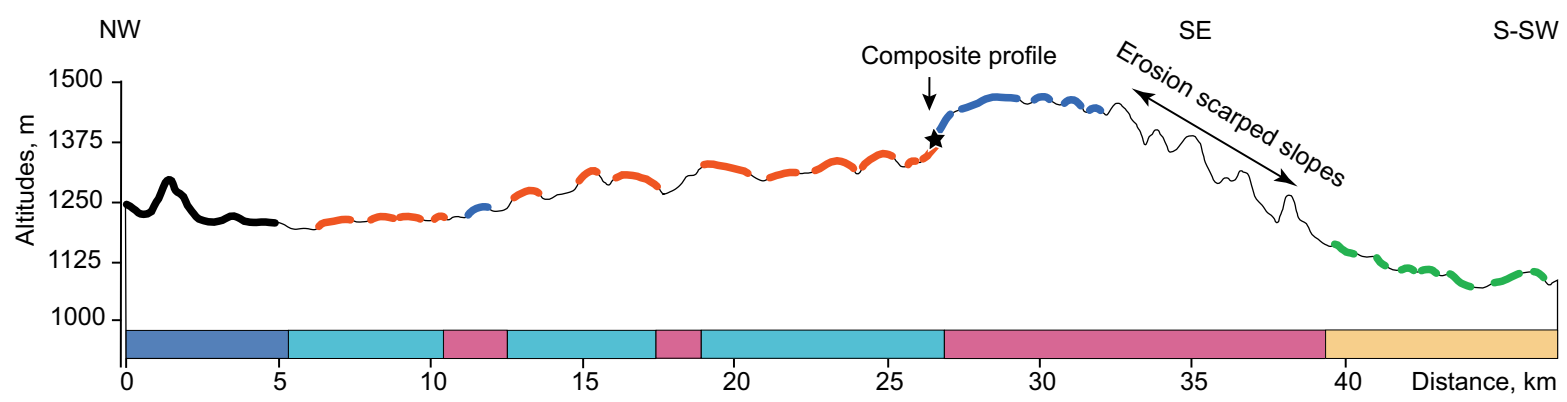
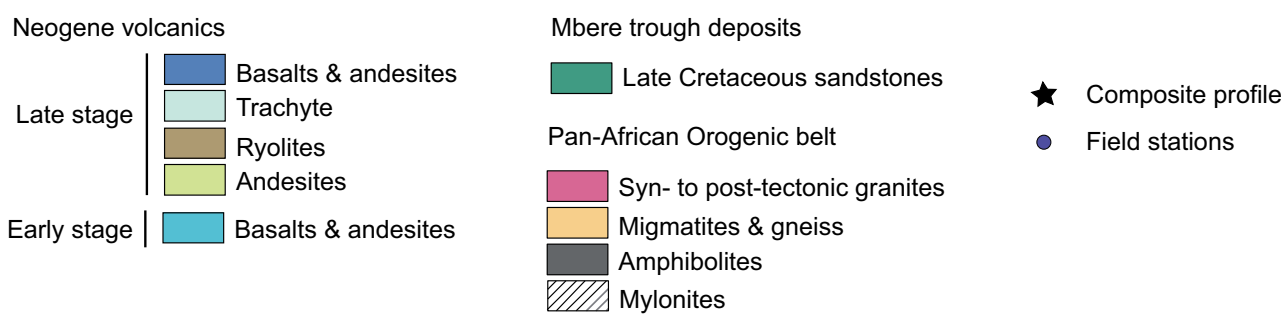
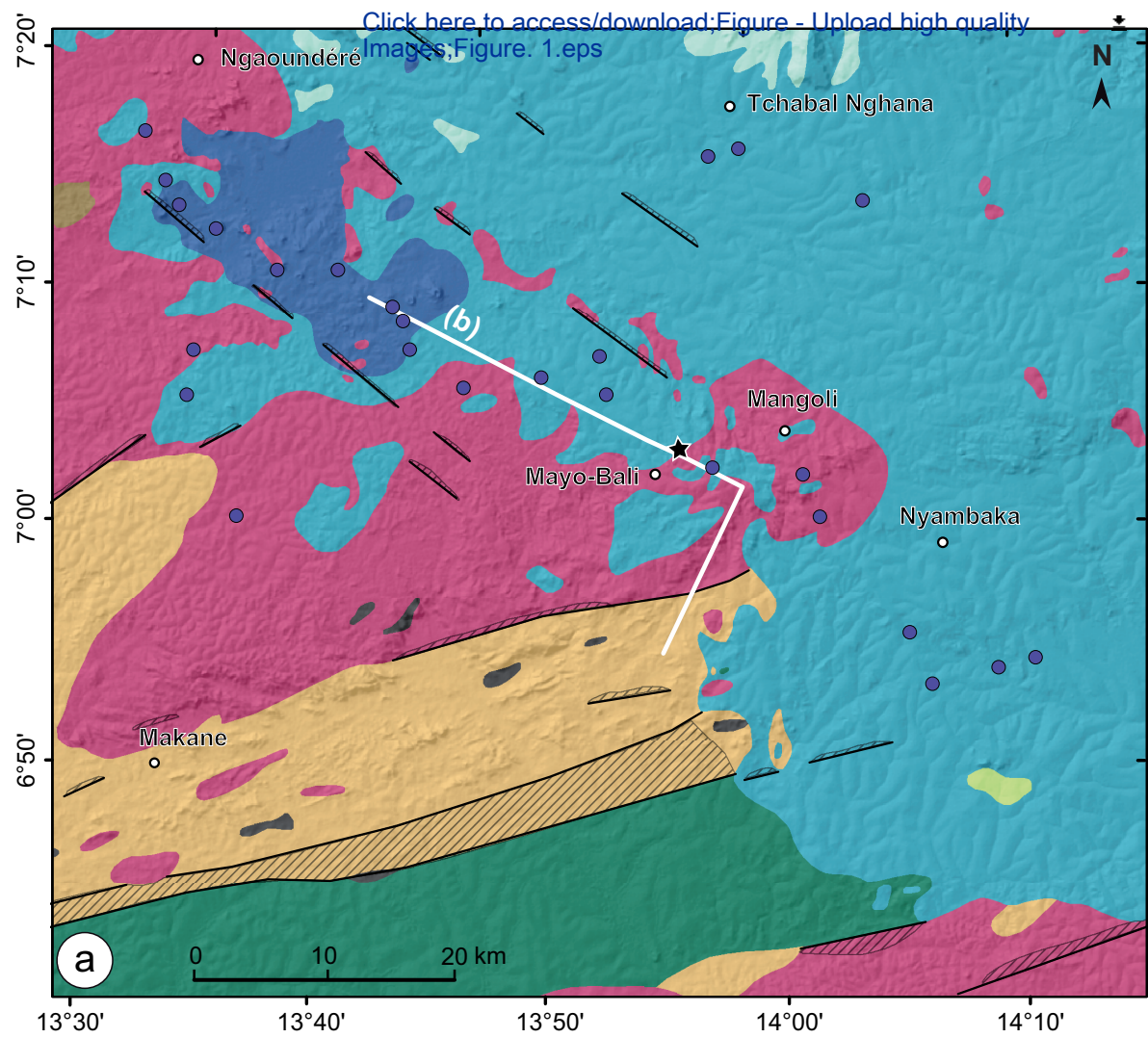
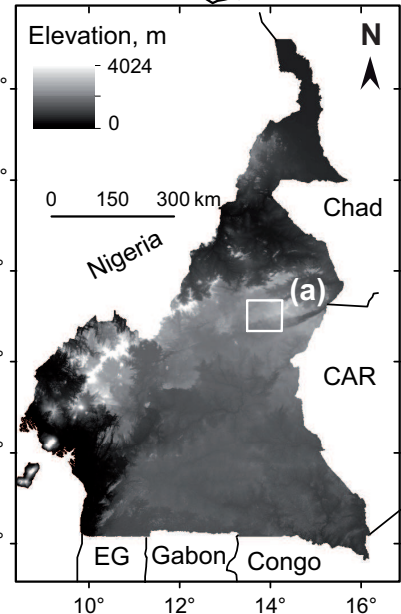
$$610 \quad \text{Ce/Ce}^* = (\text{Ce}_{\text{sample}}/\text{Ce}_{\text{chondrite}})/(\text{La}_{\text{sample}}/\text{La}_{\text{chondrite}})^{1/2} (\text{Pr}_{\text{sample}}/\text{Pr}_{\text{chondrite}})^{1/2}$$

$$611 \quad \text{Eu/Eu}^* = (\text{Eu}_{\text{sample}}/\text{Eu}_{\text{chondrite}})/(\text{Sm}_{\text{sample}}/\text{Sm}_{\text{chondrite}})^{1/2} (\text{Gd}_{\text{sample}}/\text{Gd}_{\text{chondrite}})^{1/2}$$

$$612 \quad (\text{La/Yb})_N = (\text{La}_{\text{sample}}/\text{La}_{\text{chondrite}})/(\text{Yb}_{\text{sample}}/\text{Yb}_{\text{chondrite}})$$

$$613 \quad (\text{Gd/Yb})_N = (\text{Gd}_{\text{sample}}/\text{Gd}_{\text{chondrite}})/(\text{Yb}_{\text{sample}}/\text{Yb}_{\text{chondrite}}).$$

614



(b)

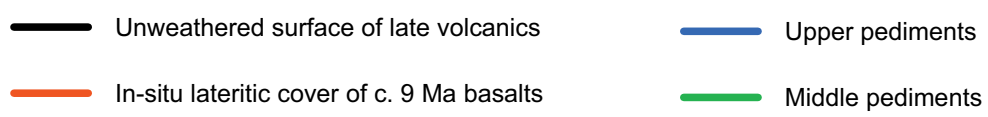


Fig. 1



Fig. 2

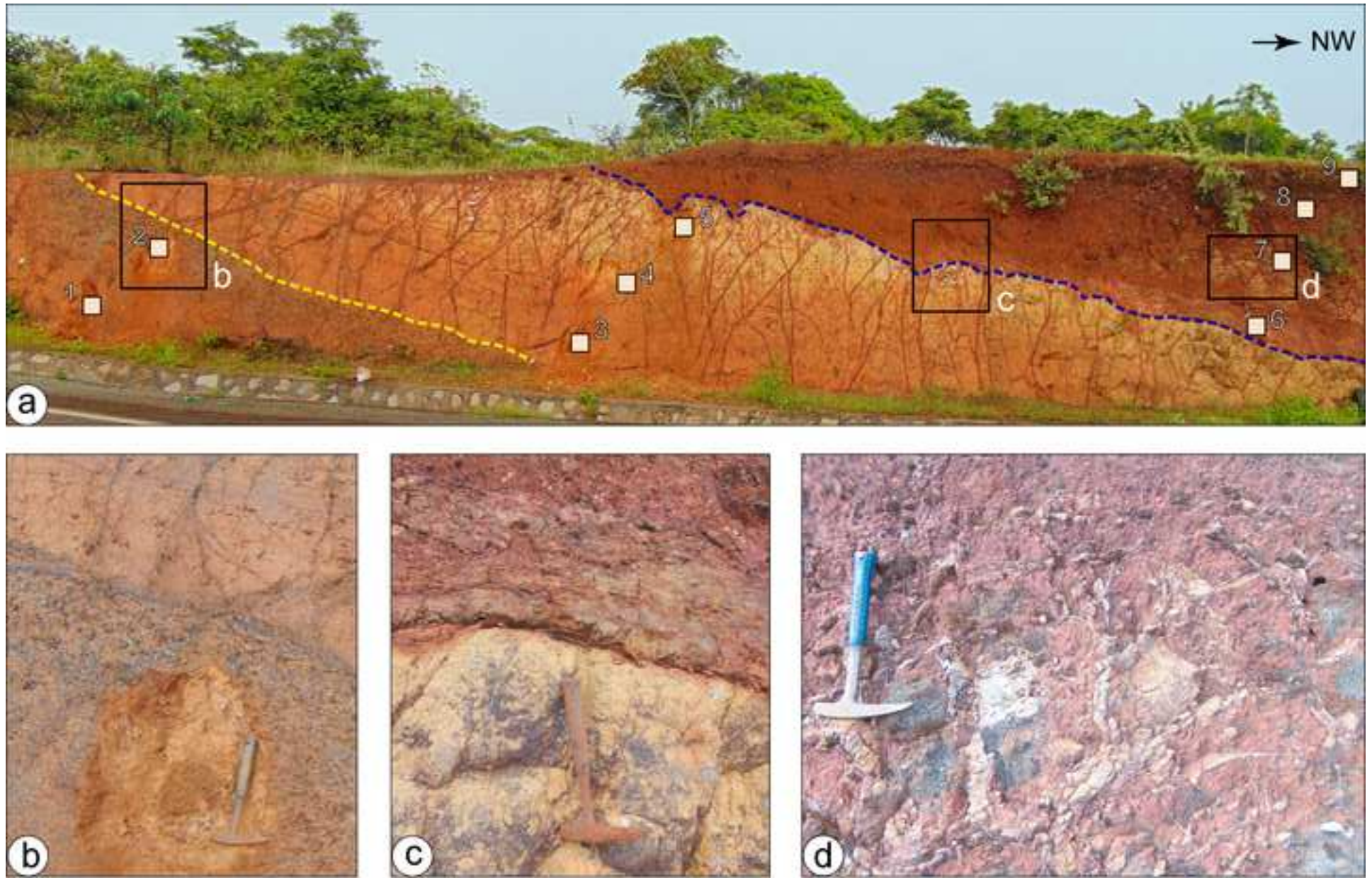


Fig. 3

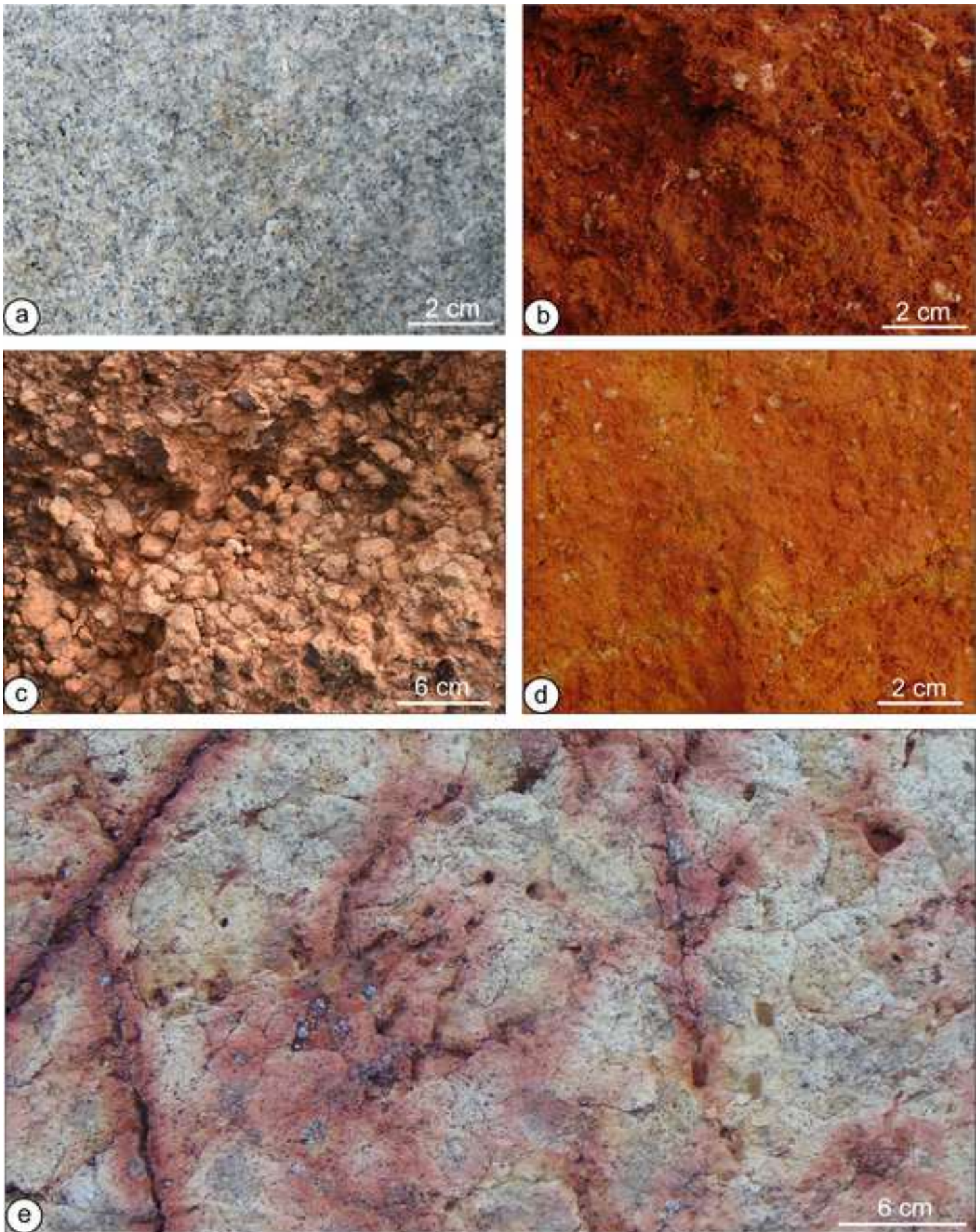


Fig. 4

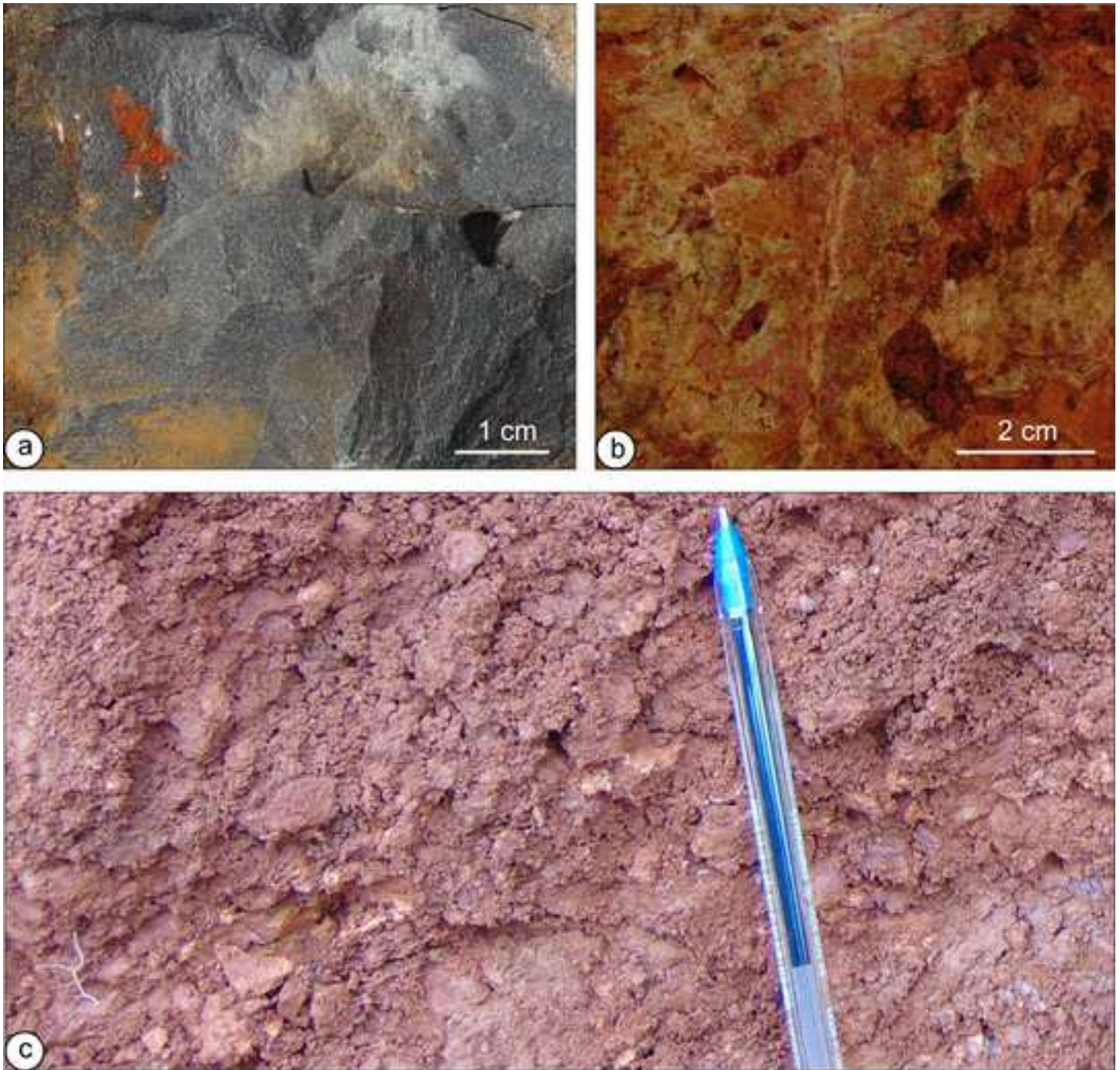


Fig. 5

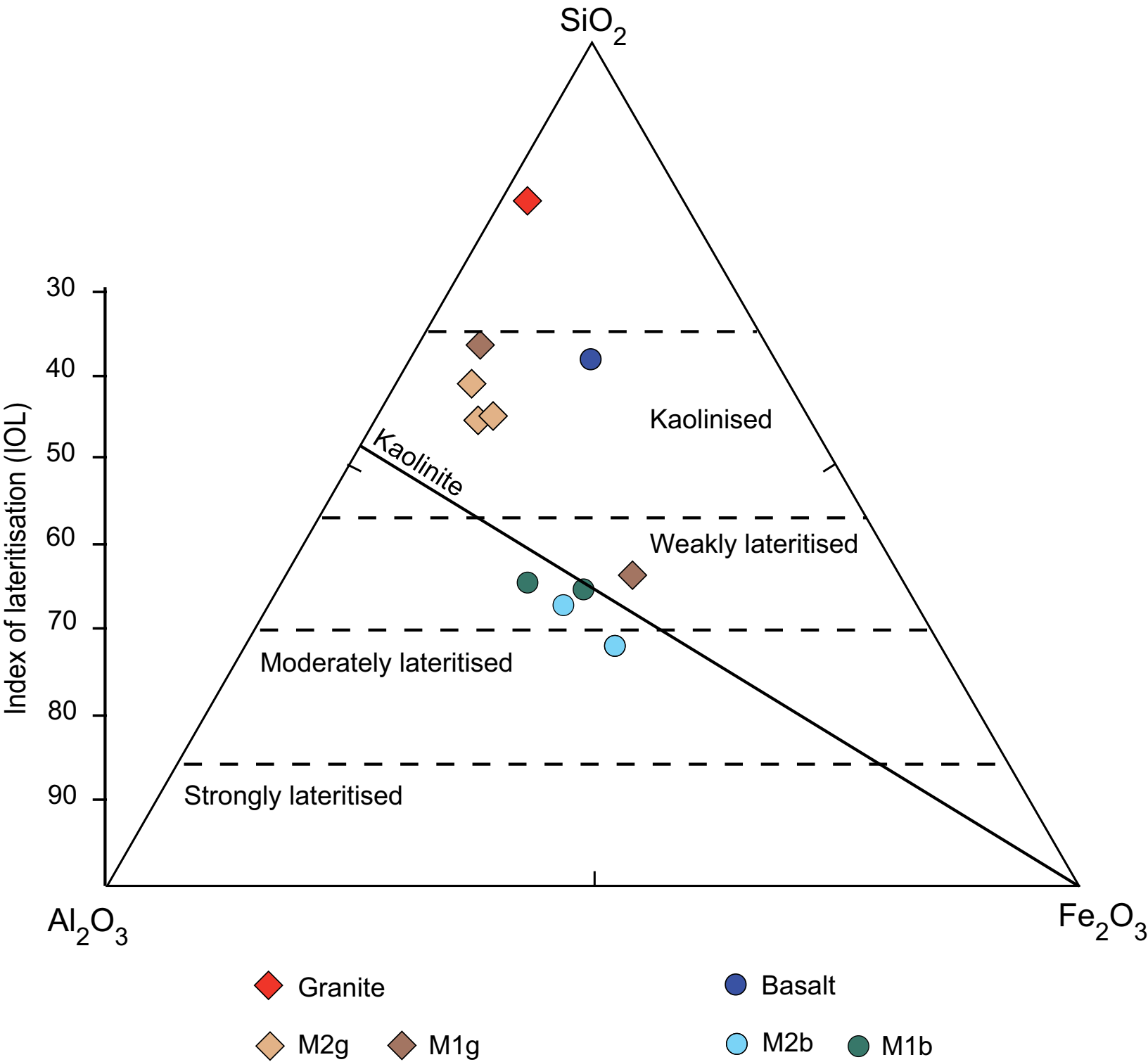


Fig. 6

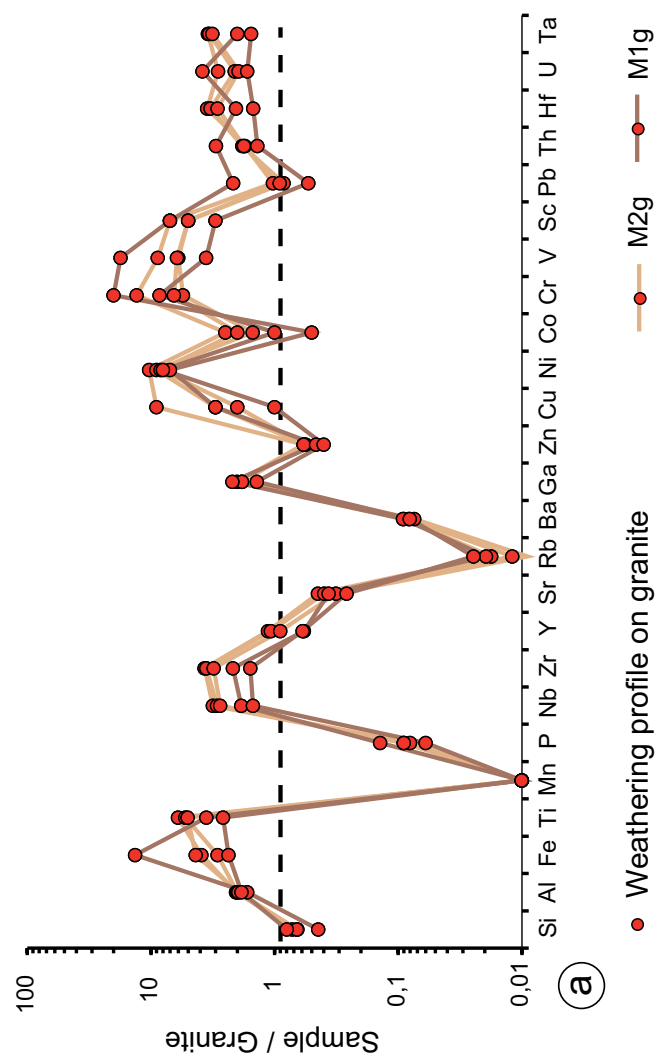
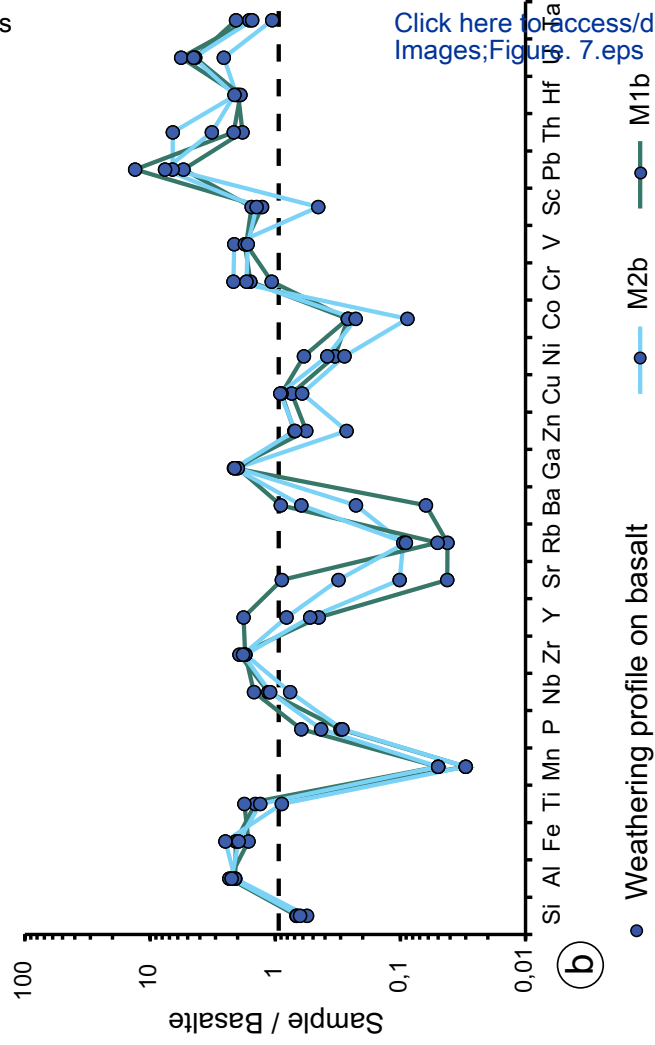
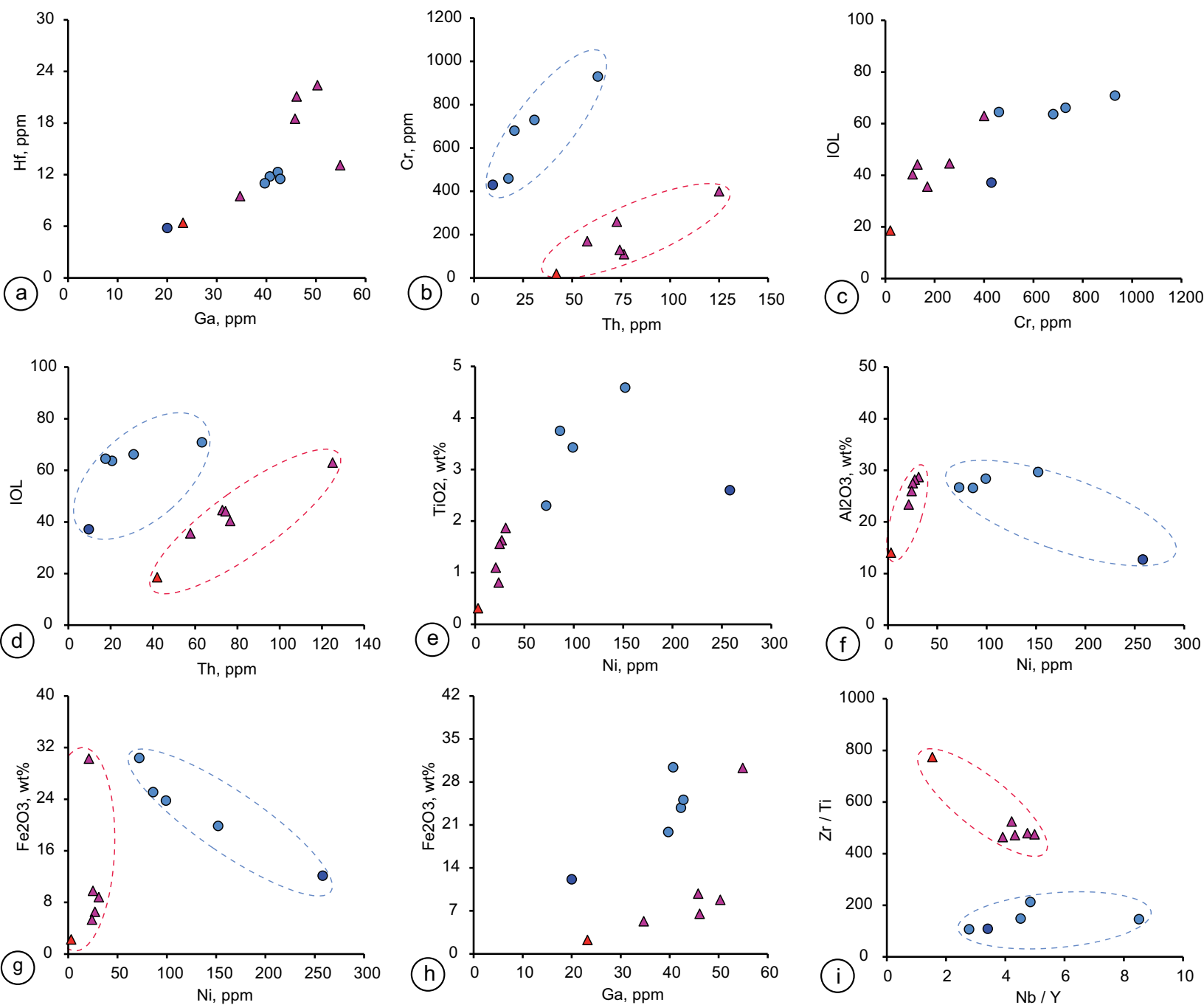


Fig. 7



● Weathering horizons on basalts
 ▲ Weathering horizons on granite

● Basalt
 ▲ Granite

Fig. 8

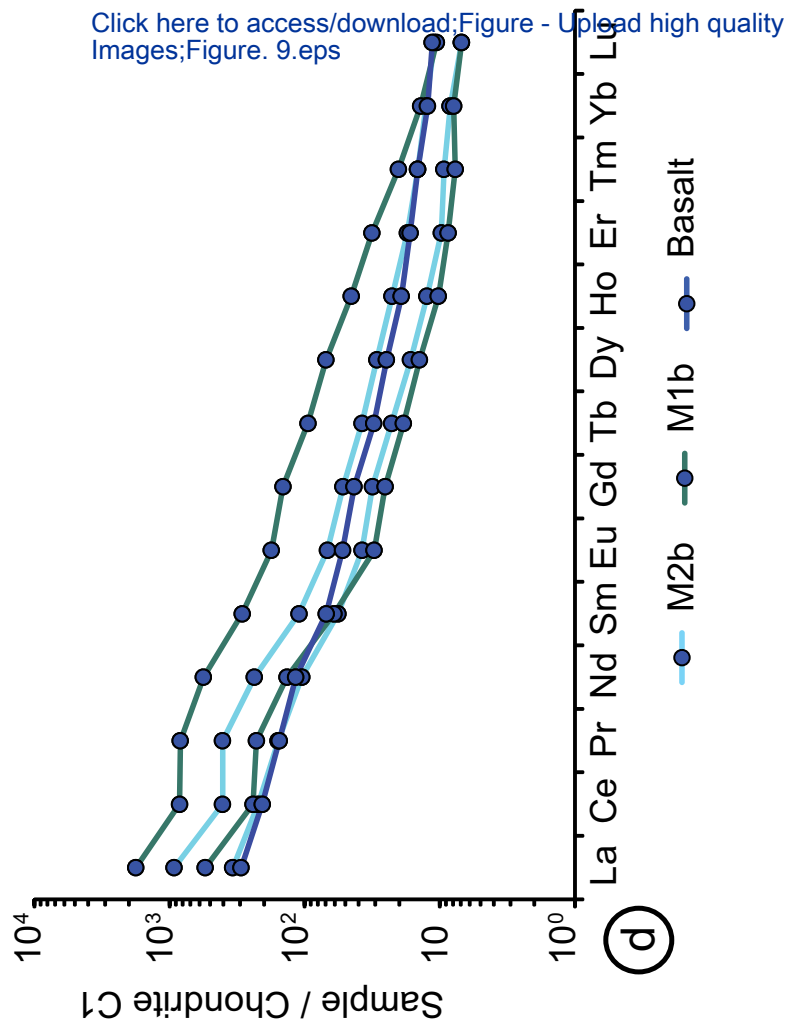
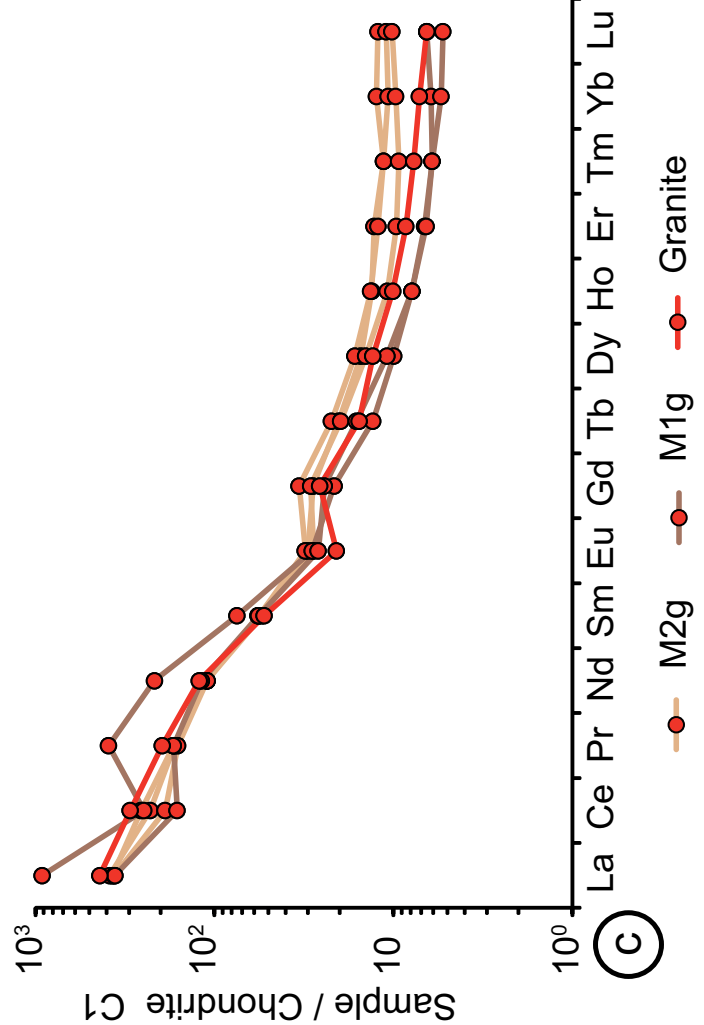
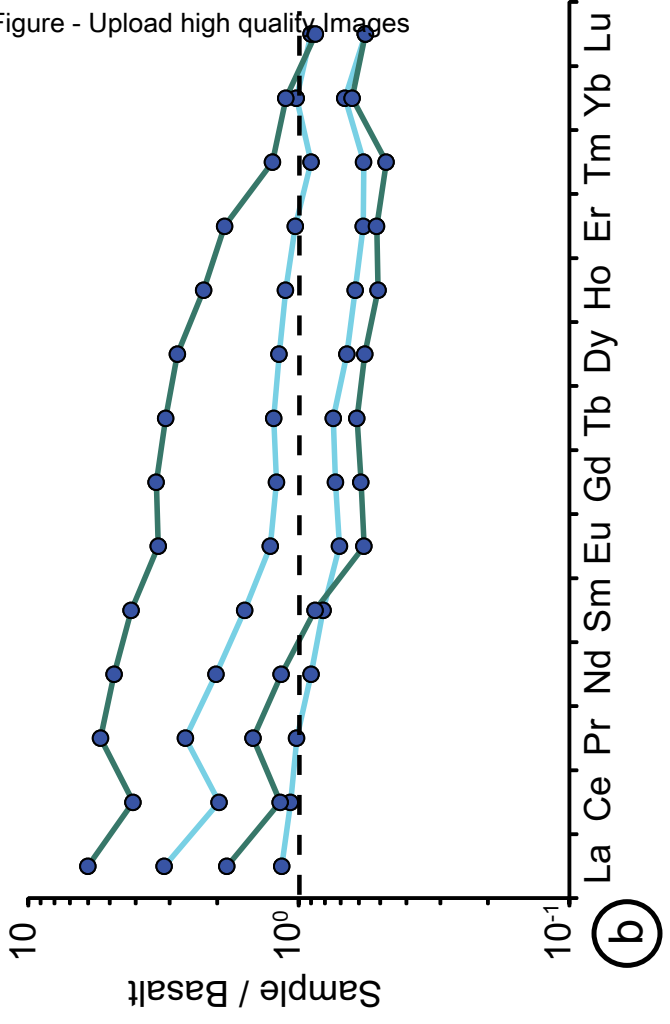
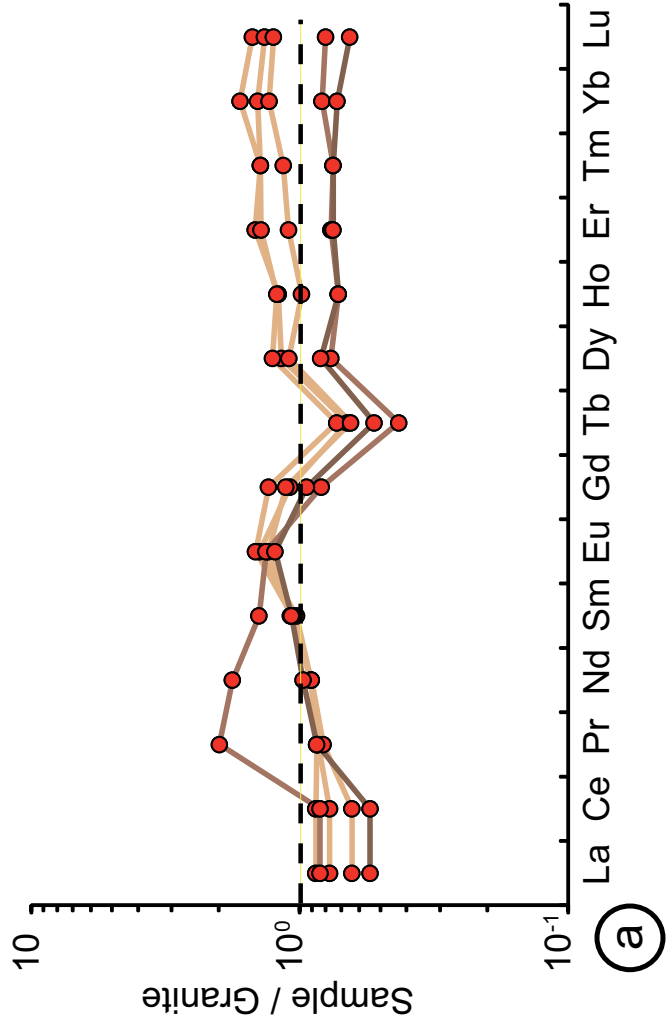


Fig. 9

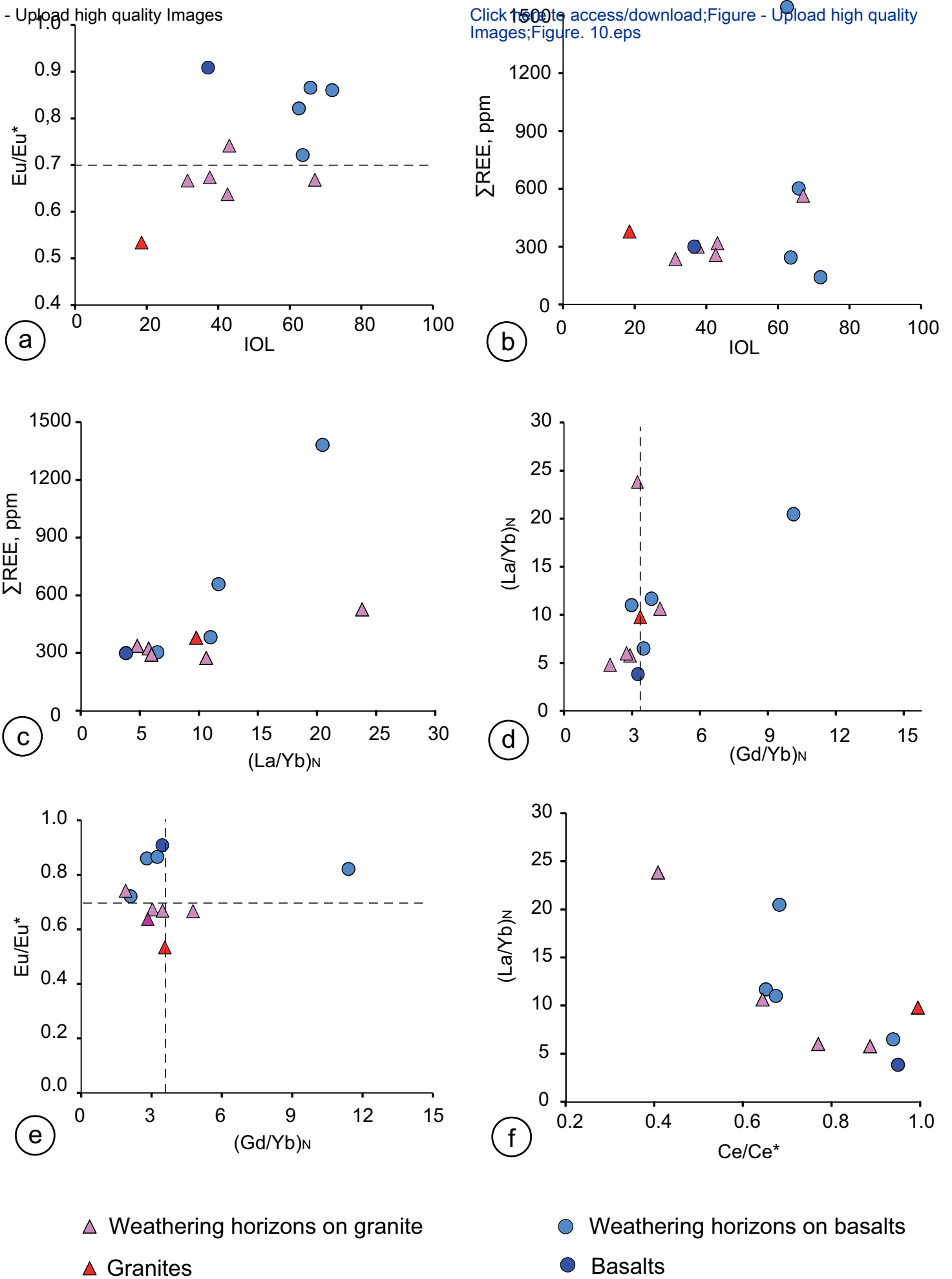
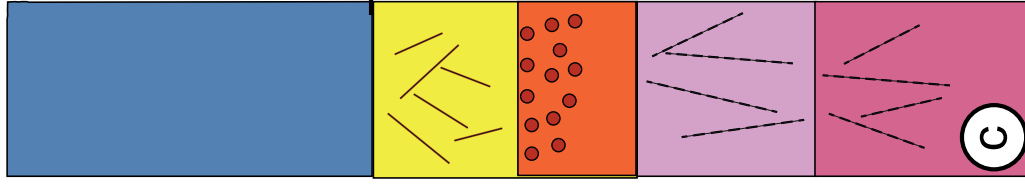


Fig. 10

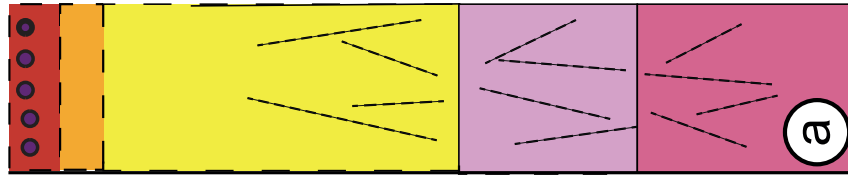
Post-Miocene, 11 Ma to modern landscape

Stage 3

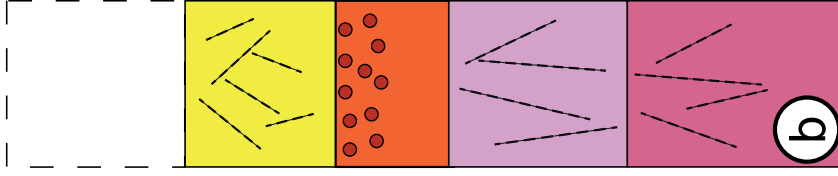


Pre-Miocene

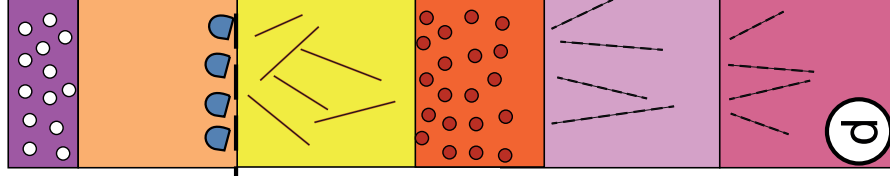
Stage 1



Stage 2



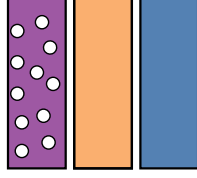
Stage 4



~ 5 m

~ 7 m

Pebbly ferruginous
Mottled clays
Basalt



lithological unconformity



Nodular ferricrete



Ferruginous carapace



Mottled clays & Fe/nodular horizon



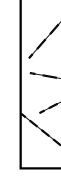
Saprolite



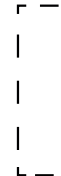
Granite



Fracturation



Eroded



In-situ Fe-nodules formation



In-situ Fe-nodules formation



Fe-coated fractures



Fig. 11

Table 1

Samples ID	Horizon ID	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	TiO ₂	CaO	MgO	Na ₂ O	K ₂ O	MnO	P ₂ O ₅	Total	LOI	IOL
MEI-9	M2b	23.5	26.7	30.4	2.3	0.02	0.11	0.01	0.06	0.03	0.29	100.42	11.30	70.8
MEI-8	M2b	26.7	28.4	23.8	3.43	0.03	0.16	0.01	0.06	0.05	0.43	99.9	13.10	66.2
MEI-7	M1b	28.3	29.7	19.85	4.59	0.06	0.14	0.01	0.02	0.05	0.62	99.26	12.60	63.6
MEI-6	M1b	28.5	26.6	25.1	3.75	0.01	0.15	0.01	0.03	0.03	0.3	99.6	12.35	64.5
BAS-MEI		42.1	12.7	12.15	2.6	10.75	11.7	2.61	1.59	0.19	0.95	99.54	1.9	37.2
MEI-5	M2g	46.7	28.7	8.82	1.87	0.02	0.04	0.01	0.05	0.01	0.09	99.56	13.20	44.5
MEI-4	M2g	51.4	28.2	6.54	1.63	0.01	0.03	0.01	0.04	0.01	0.08	100.34	15.05	40.3
MEI-3	M2g	47.2	27.5	9.81	1.56	0.12	0.03	-	0.02	0.01	0.09	98.97	15.65	44.1
MEI-2	M1g	31.6	23.4	30.3	1.1	0.02	0.03	-	0.06	0.01	0.14	99.83	16.65	63.0
MEI-1	M1g	56.8	26.0	5.33	0.81	0.01	0.03	0.01	0.08	0.01	0.06	100.47	16.85	35.5
GRA-MEI		71.5	14.05	2.26	0.31	1.32	0.44	3.38	5.43	0.04	0.08	99.88	0.93	18.6

Table 2

Samples	Horizon ID	Nb	Zr	Y	Sr	Rb	Ba	Ga	Zn	Cu	Ni	Co	Cr	V	As	Sc	Pb	Th	Hf	U	Ta
		dl: 0.1	2	0.1	0.1	0.2	0.5	0.1	2	1	1	1	10	5	5	1	2	0.05	0.1	0.05	0.1
MEI-9	M2b	68.8	489	14.2	93.6	4.5	162	40.7	29	28	72	5	930	460	18	10	33	63.1	11.8	6.45	3.8
MEI-8	M2b	99.4	509	22	288	4.3	443	42.3	75	42	99	13	730	359	6	31	38	30.8	12.3	11.2	5.5
MEI-7	M1b	134	491	48.3	817	2.4	645	39.7	76	41	152	15	680	377	-	28	66	20.6	11	10.9	7.4
MEI-6	M1b	103	546	12.1	38.9	2	44.7	42.8	61	34	86	15	460	369	8	34	27	17.5	11.5	14.1	5.8
BAS-MEI		90.6	282	26.6	923	47.5	715	20	108	46	258	57	430	216	-	22	5	9.58	5.8	2.47	3.6
MEI-5	M2g	68.3	882	15.8	92.7	4.9	93	50.3	29	9	31	5	260	185	5	14	33	72.8	22.4	9.43	3.8
MEI-4	M2g	63.2	855	15	82.6	3.3	84.9	46.1	28	3	27	3	110	126	-	10	27	76.5	21.1	6.91	3.7
MEI-3	M2g	59.8	747	12.6	66.4	2.5	76.7	45.8	29	2	25	4	130	129	-	10	29	74.3	18.5	6.43	3.5
MEI-2	M1g	40.4	522	8.1	75.8	5.4	94.7	54.9	23	3	21	1	400	370	14	14	69	125	13.1	12.6	2.2
MEI-1	M1g	32.5	376	8.3	54.4	6.8	83.5	34.7	20	1	24	2	170	75	-	6	17	57.7	9.5	5.48	1.7
GRA-MEI		21.7	240	14.1	208	277	1035	23.2	50	1	3	2	20	21	-	2	32	42	6.4	3.3	1.1

Table 3

Samples	Horizon ID	dl :	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	ΣREE	La/Y	Ce/Ce*	Eu/Eu*	(La/Yb) _N	(Gd/Yb) _N
			0.1	0.1	0.02	0.1	0.03	0.02	0.05	0.01	0.05	0.01	0.03	0.01	0.03	0.01	0.03	0.01				
MEI-09	M2b		80.6	135	14.5	47.9	8.37	2.12	6.27	0.82	4.04	0.68	1.56	0.23	1.35	0.17	303.66	5.68	0.94	0.84	6.49	3.72
MEI-08	M2b		219	248	37.5	107.5	16.3	3.82	10.35	1.36	7.19	1.23	2.78	0.36	2.04	0.27	657.70	9.95	0.65	0.85	11.67	4.06
MEI-07	M1b		420	516	77.2	256	42.8	9.91	28.8	3.41	17.1	2.47	5.07	0.5	2.23	0.26	1381.75	8.70	0.68	0.81	20.47	10.33
MEI-06	M1b		128.5	147.5	21.1	61.7	8.96	1.72	5.05	0.67	3.47	0.56	1.39	0.19	1.27	0.17	382.25	10.62	0.67	0.74	11.00	3.18
BAS-MEI			69.8	126	14.3	53.2	10.25	2.95	8.57	1.11	6.09	1.05	2.65	0.36	1.98	0.28	298.59	2.62	0.95	0.91	3.83	3.46
MEI-05	M2g		88.1	157.5	15.7	50.3	8.01	1.69	5.58	0.73	3.74	0.72	2.05	0.28	2.00	0.30	336.70	5.58	1.01	0.73	4.79	2.23
MEI-04	M2g		91.2	140	15.5	50.5	8.32	1.75	6.69	0.8	4.04	0.73	1.95	0.28	1.72	0.27	323.75	6.08	0.89	0.68	5.76	3.11
MEI-03	M2g		86	115.5	14.8	50.1	8.44	1.57	5.77	0.71	3.51	0.59	1.54	0.23	1.56	0.25	290.62	6.83	0.77	0.65	5.99	2.96
MEI-02	M1g		217	152	36.2	98.7	11.05	1.6	4.26	0.47	2.45	0.43	1.07	0.15	0.99	0.16	526.53	26.79	0.41	0.67	23.82	3.44
MEI-01	M1g		85.1	98.9	15.7	53.9	8.37	1.48	4.83	0.58	2.67	0.43	1.05	0.15	0.87	0.13	274.16	10.25	0.64	0.67	10.63	4.44
GRA-MEI			103.5	181	18.15	55.5	7.8	1.17	5.13	0.56	3.2	0.55	1.36	0.19	1.15	0.16	379.42	7.34	0.99	0.53	9.78	3.57