



**HAL**  
open science

## **Erosion mode and history of Eastern Adamaoua landscapes (Cameroon): Superimposed lateritic weathering of granites and basalts**

Mathieu Nouazi Momo, Anicet Beauvais, Gatien Romuald Kenfack Nguemo, Ethel Nkongho Ashukem, Edima Roland Yana, Salomon César Nguemhe-Fils, Rachel Ngo Nyouma, Alex Chimeu Akaba

► **To cite this version:**

Mathieu Nouazi Momo, Anicet Beauvais, Gatien Romuald Kenfack Nguemo, Ethel Nkongho Ashukem, Edima Roland Yana, et al.. Erosion mode and history of Eastern Adamaoua landscapes (Cameroon): Superimposed lateritic weathering of granites and basalts. *CATENA*, 2023, 226, pp.107071. 10.1016/j.catena.2023.107071 . hal-04050321

**HAL Id: hal-04050321**

**<https://hal.science/hal-04050321>**

Submitted on 29 Mar 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

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

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

3  
4 Mathieu Nouazi Momo<sup>1</sup>, Anicet Beauvais<sup>2</sup>, Gatien Romuald Kenfack Nguemo<sup>3</sup>, Ethel

5 Nkongho Ashukem<sup>1</sup>, Edima Roland Yana<sup>1</sup>, Salomon César Nguemhe-Fils<sup>1</sup>, Rachel Ngo

6 Nyouma<sup>1</sup>, Alex Chimeu Akaba<sup>4</sup>

7  
8 <sup>1</sup> Institute of Geological and Mining Research (IRGM), P.O. Box 4110 Yaoundé, Cameroon

9 <sup>2</sup> Aix-Marseille Univ, CNRS, IRD, INRAE, CEREGE, BP 80, 13545, Aix-en-Provence,

10 Cedex 4, France

11 <sup>3</sup> University of Dschang, Faculty of Science - Department of Earth Sciences. PO Box 67

12 Dschang - Cameroon

13 <sup>4</sup> University of Yaoundé 1, Faculty of Science, Department of Earth Sciences. PO Box 337

14 Yaoundé, Cameroon

15  
16 <https://doi.org/10.1016/j.catena.2023.107071>

17  
18  
19  
20  
21  
22  
23  
24 \*Corresponding author Email: [nouazimat@yahoo.fr](mailto:nouazimat@yahoo.fr)

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  $\mu\text{m}$ . 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-MS81<sup>TM</sup> + whole  
157 rock package ME-ICP06; [www.alsglobal.com](http://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 ( $\text{SiO}_2$ -  
167  $\text{Al}_2\text{O}_3$ - $\text{Fe}_2\text{O}_3$ ), 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.  $35^\circ$  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<sub>2</sub> content and increasing  
205 contents of Fe<sub>2</sub>O<sub>3</sub> and Al<sub>2</sub>O<sub>3</sub> relative to the respective parent rocks (Fig. 6). The maximum  
206 depletion of SiO<sub>2</sub> and element enrichment of Fe<sub>2</sub>O<sub>3</sub> 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 ( $\sim 0.6$ ) with well-  
267 marked anomalies (Fig. 9c), while the basalt litho-section has higher values and lower  
268 anomalies in ( $\sim 0.8$ ; 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  $\text{FeO}_2$  ( $r^2=-0.88$ ) 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  $\text{Fe}_2\text{O}_3$  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 relics 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

401 Acknowledgements- The IRD program JEAI is thanked for funding and support to the  
402 MORPHOCAM project under which this work has been done. Financial support of the APIC  
403 annual programs (2019-2020) from the “Centre de Recherche et d’Enseignement des  
404 Géosciences de l’Environnement” (CEREGE) is also acknowledged. IRD (Disco department)  
405 is also thanked for granting MNM stays at Cerege, Aix Marseille Université, OSU Pytheas,  
406 France. Remarks and suggestions from two anonymous reviewers and the editor Dr.  
407 Scarciglia are also much acknowledged.

408

409

410

411 **References**

- 412 Allix, P. Legoux, O., Robert, P., 1984. Essai d'interprétation géodynamique de l'évolution  
413 Mésozoïque des sous-bassins du fossé de la Bénoué. Bull. Soc. Géol., France (7), 26,  
414 1061-1068.
- 415 Ambrosi, J-P., Nahon, D., 1986a. The epigenetic replacement of kaolinite by hematite in  
416 laterite- petrographic evidence and the mechanisms involved. *Geoderma* 37(4), 283-294.
- 417 Ambrosi, J-P., Nahon, D., 1986b. Petrological and geochemical differentiation of lateritic iron  
418 crust profiles. *Chemical Geology* 57, 371-393.
- 419 Babechuk, M.G., Widdowson, M., Kamber, B.S., 2014. Quantifying chemical intensity and  
420 trace element release from two contrasting profiles, Decan Traps, India. *Chemical*  
421 *geology* 365, 56-75.
- 422 Beauvais, A., 1999. Geochemical balance of laterization processes and climatic signaturs in  
423 weathering profiles overlain by ferricretes in Central Africa. *Geochimica et*  
424 *Cosmochimica Acta* 63 (1999), 3939-3957.
- 425 Beauvais, A., 2009. Ferricrete biochemical degradation on the rainforest savannas boundary  
426 of Central African Republic. *Geoderma* 150, 379-388.
- 427 Beauvais, A., Bonnet, N.J., Chardon, D., Arnaud, N., Jayananda, M., 2016. Very long-term  
428 stability of passive margin escarpment constrained by  $^{40}\text{Ar}/^{39}\text{Ar}$  dating of K-Mn  
429 oxides. *Geology* 44, 299-302. <https://doi.org/10.1130/G37303.1>
- 430 Beauvais, A., Chardon, D., 2013. Modes, tempo, and spatial variability of Cenozoic cratonic  
431 denudation: The West African example. *Geochem. Geophys. Geosyst.* 5(5), 1590-1608.  
432 doi:10.1002/ggge.20093.
- 433 Beauvais, A., Ruffet, G., Hénocque, O., Colin, F., 2008. Chemical and physical erosion  
434 rhythms of the West African Cenozoic morphogenesis: The  $^{39}\text{Ar}$ - $^{40}\text{Ar}$  dating of

435 supergene K-Mn oxides. *Journal of geophysical research. Earth surface* 113, F04007,  
436 doi:10.1029/2008JF000996.

437 Boulangé, B., Colin, F., 1994. Rare-earth element mobility during conversion of nepheline  
438 syenite into lateritic bauxite at Passa Quatro, Minas Gerais, Brazil. *Appl.Geochem.* 9,  
439 701-711.

440 Braun, J.J., Pagel, M., Herbillon, A., Rosin, C., 1993. Mobilization and redistribution of REEs  
441 and thorium in syenitic lateritic profile: A mass balance study. *Geochim. Cosmochim.*  
442 *Acta* 57, 4419-4434.

443 Brown, D.J., Helmke, P.A., 2003. Robust geochemical indices for redox and weathering on a  
444 granitic laterite landscape in Central Uganda. *Geochim. Cosmochim. Acta* 67(15), 2711-  
445 2723.

446 Burke, K., 2001. Origin of the Cameroon line of volcano-capped swells. *The Journal of*  
447 *Geology* 109, 349-362.

448 Burke, K., Gunnell, Y., 2008. The African erosion surface: a continental-scale synthesis of  
449 geomorphology, tectonics, and environmental change over the past 180 million years.  
450 Geological Society of America, *Memoir* 201 1 - 66.

451 Chardon, D., Grimaud, J.L., Beauvais, A., Bamba, O., 2018. West African lateritic pediments:  
452 Landform-regolith evolution processes and mineral exploration pitfalls. *Earth science*  
453 *review* 179, 124-146.

454 Chardon, D., Grimaud, J-L., Rouby, D., Beauvais, A., Christophoul, F., 2016. Stabilization of  
455 large drainage basins over geological timescales: Cenozoic West Africa, hot spot swell  
456 growth and the Niger River. *Geochem. Geophys. Geosyst.* 17, (3), 1164-1181.

457 Colin, F., A., Beauvais, G., Ruffet, Hénocque, O., 2005. First  $^{40}\text{Ar}/^{39}\text{Ar}$  geochronology of  
458 lateritic manganiferous pisolites: Implications for the Palaeogene history of a West  
459 African landscape. *Earth Planet Science Letter*, 238, 172-188.

460 Compton, S.J., White, A.R., Smith, M., 2003. Rare earth element behavior in soils and salt  
461 pan sediments of a semi-arid granitic terrain in the Western Cape, South Africa.  
462 *Chemical geology* 201, 239-255.

463 Delor, C., Bernard, J., Tucker, R.D., Roig, J-Y., Bouyo Houketchang, M., Coueffe, R., Blein,  
464 O., 2021. 1/1000000-scale geologic map of Cameroon. Second edition.

465 Deruelle, B., Moreau, C., Nkoumbou, C., Kambou, R., Lissom, J., Njonfang, E., Ghogomu,  
466 T.R., Nono, A., 1991. The Cameroon Line: a review. In: Kampunzu, A.B., Lubala, R.T.  
467 (Eds.), *Magmatism in Extensional Structural Settings, The Phanerozoic African Plate*.  
468 Springer-Verlag, Berlin, pp. 274-327.

469 Fosso, J., Ménard, J.-J., Bardintzeff, J.-M., Wandji, P., Tchoua, F. M., Bellon, H., 2005.  
470 Lavas from the Mount Bangou area: A first Eocene volcanic episode with transitional  
471 affinities of Cameroon Line. *C. R. Géoscience* 337(3), 315-325.

472 Ganwa, A.A., Wolfgang, S., Wolfgang, F., Shang, C.K., 2011. Geochemistry of magmatic  
473 rocks and time constraints on deformational phases and shear zone slip in the Méiganga  
474 area, central Cameroon. *International Geology Review*, 53: 7, 759-784. doi:  
475 10.1080/00206810903211161

476 Girod, M., Dautria, J.M., Bali, E., Soba, D., 1984. Pétrologie-Estimation de la profondeur du  
477 Moho sous le massif volcanique de l'Adamaoua (Cameroun), à partir de l'étude des  
478 enclaves de lherzolite. *Compte rendu de l'Académie des Sciences, Paris*, 298, 2, 699-704.

479 Grandin, G., 1976. Aplanissements cuirassés et enrichissement des gisements de manganèse  
480 dans quelques régions d'Afrique de l'Ouest. *Mémoires de l'ORSTOM* 82, 1-276.

481 Grimaud, J.-L., Chardon, D., Beauvais, A., 2014. Very long-term incision dynamics of big  
482 rivers. *Earth. Planet. Sci. letters* 405, 74-84.

483 Jean, A., Beauvais, A., Chardon, D., Arnaud, N., Jayananda, M., Mathe, P.E., 2020.  
484 Weathering history and landscape evolution of Western Ghats (India) from  $^{40}\text{Ar}/^{39}\text{Ar}$   
485 dating of supergene K–Mn oxides. *Journal of the Geological Society* 177, 523-536.  
486 <https://doi.org/10.1144/jgs2019-048>

487 Kagou Ndongmo, A., Nkouathio, D.G., Pouclet, A., Bardintzeff, J-M., Wandji, P., Nono, A.,  
488 Guillou, H., 2010. The discovery of Late Quaternary basalt on Mount Bambouto:  
489 implications for recent widespread volcanic activity in the southern Cameroon Line.  
490 *Journal of African Earth Sciences* 57, 96-108.

491 Lasserre, M., 1961. Etude géologique de la partie orientale de l'Adamaoua (Cameroun  
492 central). *Territoire Camerounais. Bulletin de la Direction des mines et de la Géologie* 4,  
493 130 p, carte 1/500000.

494 Löhr, S.C., Grigorescu, M., Cox M.E., 2013. Iron nodules in ferric soils of the Fraser Coast,  
495 Australia: relicts of laterisation or features of contemporary weathering and pedogenesis?  
496 *Soil Research* 51, 77-93. <http://dx.doi.org/10.1071/SR12372>

497 Marzoli, A., Piccirillo, E.M., Renne, P.R., Bellieni, G., Iacumin, M., Nyobe, J.B., Tongwa,  
498 A.T., 2000. The Cameroon Volcanic Line revisited: Petrogenesis of continental basaltic  
499 magmas from lithospheric and asthenospheric mantle sources. *Journal of Petrology* 41,  
500 pp. 87-109.

501 Marzoli, A., Renne, P. R., Piccirillo, E. M., Francesca, C., Bellieni, G., Mel, A. J., Nyobe, J.  
502 B., N'ni, J., 1999. Silicic magmas from the continental Cameroon Volcanic Line (Oku,  
503 Bambouto and Ngaoundéré):  $^{40}\text{Ar}/^{39}\text{Ar}$  dates, petrology, Sr-Nd-O isotopes and their  
504 petrogenetic significance. *Contribution Mineral Petrology* 135, 133-150

505 Mc Donough, W.F., Sun, S.S., 1995. The composition of the Earth. *Chemical geology* 120,  
506 223253.

507 Momo Nouazi, M., Beauvais, A., Tematio, P., Yemefack, M., 2019. Differentiated Neogene  
508 bauxitization of volcanic rocks (western Cameroon): Morpho-geological constraints on  
509 chemical erosion. *Catena* 194, 104685.

510 Mordberg, L.E., 1996. Geochemistry of trace elements in Paleozoic bauxite profiles in  
511 northern Russia. *Journal of geochemical exploration* 57, 187-199.

512 Muller, J-P., Bocquier, G., 1986. Dissolution of kaolinites and accumulation of iron oxides in  
513 lateritic-ferruginous nodules: Mineralogical and microstructural transformations.  
514 *Geoderma* 37(2), 113-136.

515 Nahon, D., 1991. Introduction to the petrology of soils and chemical weathering. A Wiley-  
516 Interscience Publication, 313 p.

517 Nguetnkam, J-P., Solleiro-Rebolledo, E., Díaz-Ortegab, J., Tematio, P., 2020. Evaluating  
518 weathering of palaeosols in Cameroon (Central Africa) as a tool for paleoenvironmental  
519 reconstruction. *Catena* 194, 104688. <https://doi.org/10.1016/j.catena.2020.104688>

520 Nyakairu, G.W.A., Koeberl, C., 2001. Mineralogical and chemical composition and  
521 distribution of rare earth elements in clay-rich sediments from central Uganda.  
522 *Geochemical journal* 35,13-28.

523 Sawadogo, B., Bamba, O., Chardon, D., 2020. Landform-regolith mapping in the West  
524 African context. *Ore Geology Reviews* 103782.

525 Schellmann, W., 1994. Geochemical differentiation in laterite and bauxite formation. *Catena*  
526 21, 131-143.

- 527 Su, N., Yang, S., Guo, Y., Yue, W., Wang, X., Yin, P., Huang, X., 2017. Revisit of rare earth  
528 element fractionation during chemical weathering and river sediment transport. *Geochem.*  
529 *Geophys. Geosyst.* 18, 935-955. Doi:10.1002/2016GC006659.
- 530 Tardy, Y., 1997. *Petrology of Laterites and Tropical Soils*. Balkema, Rotterdam, 408 p.
- 531 Tardy, Y., Nahon, D., 1985. Geochemistry of laterites, stability of Al-goethite, Al-hematite,  
532 and Fe<sup>3+</sup>-kaolinite in bauxites and ferricretes: an approach to the mechanism of  
533 concretion formation. *American Journal of Science* 285, 865-903.
- 534 Tardy Y., Roquin C., 1998. *Dérive des continents, paléoclimats et altérations tropicales*.  
535 Editions BRGM, Orléans, 473 p.
- 536 Tchouatcha, S.M., Njiké Ngaha P.R., Magdy Salah, M., Amr Said, D., Ekodeck, G.E., 2010.  
537 Existence of late continental deposits in the Mbere and Djerem sedimentary basins (North  
538 Cameroon): Palynologic and stratigraphic evidence. *Journal of Geology and Mining*  
539 *Research* Vol. 2(6), 159-169.
- 540 Thomas M. F., 1994. *Tropical geomorphology in the tropics. A study of weathering and*  
541 *denudation in low latitudes*. John Wiley & Sons, 460 p.
- 542 Vasconcelos, P., Carmo, I.O., 2018. Calibration denudation chronology through <sup>40</sup>Ar/<sup>39</sup>Ar  
543 weathering chronology. *Earth Science Reviews*, S0012-8252(17)30632-3,  
544 doi:10.1016/j.earscirev.2018.01.003
- 545 Winchester, J.A., Floyd, P.A., 1977. Geochemical Discrimination of Different Magma Series  
546 and Their Differentiation Product Using Immobile Elements. *Chemical Geology* 20, 325-  
547 343.
- 548 Zarasvandi, A., Carranza, E.J.M., Ellahi, S.S., 2012. Geological, geochemical and  
549 mineralogical characteristics of the Deh-Now bauxite deposits, Zagros fold belt, Iran. *Ore*  
550 *geological review* 48, 125-138.



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) TiO<sub>2</sub> vs Ni; f) Al<sub>2</sub>O<sub>3</sub> vs Ni; g) Fe<sub>2</sub>O<sub>3</sub> vs Ni; h) Fe<sub>2</sub>O<sub>3</sub> 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)<sub>N</sub>; d) (La/YB)<sub>N</sub> vs (Gd/Yb)<sub>N</sub>;  
592 e) Eu/Eu\* vs (Gd/Yb)<sub>N</sub>; f) (La/YB)<sub>N</sub> 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.

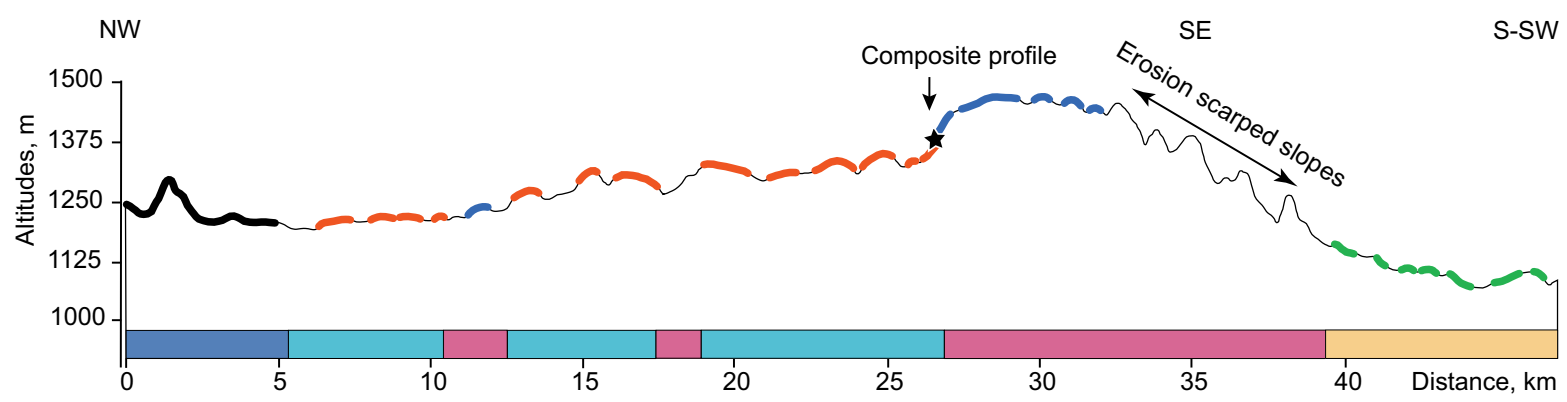
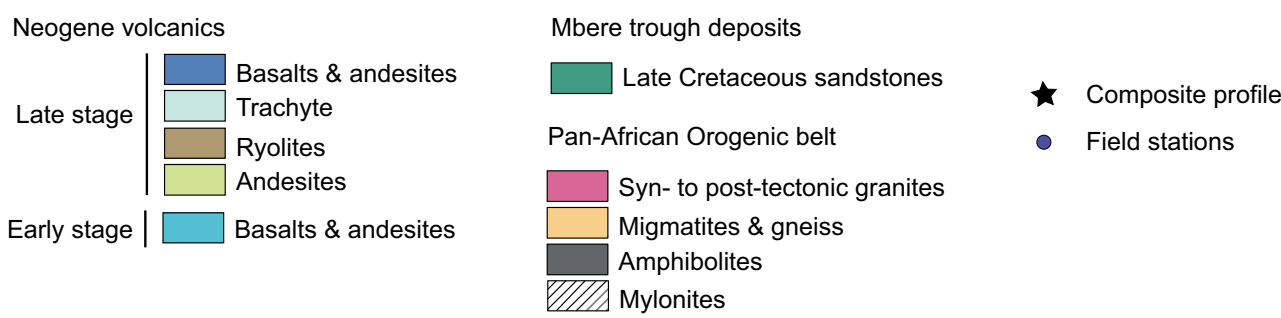
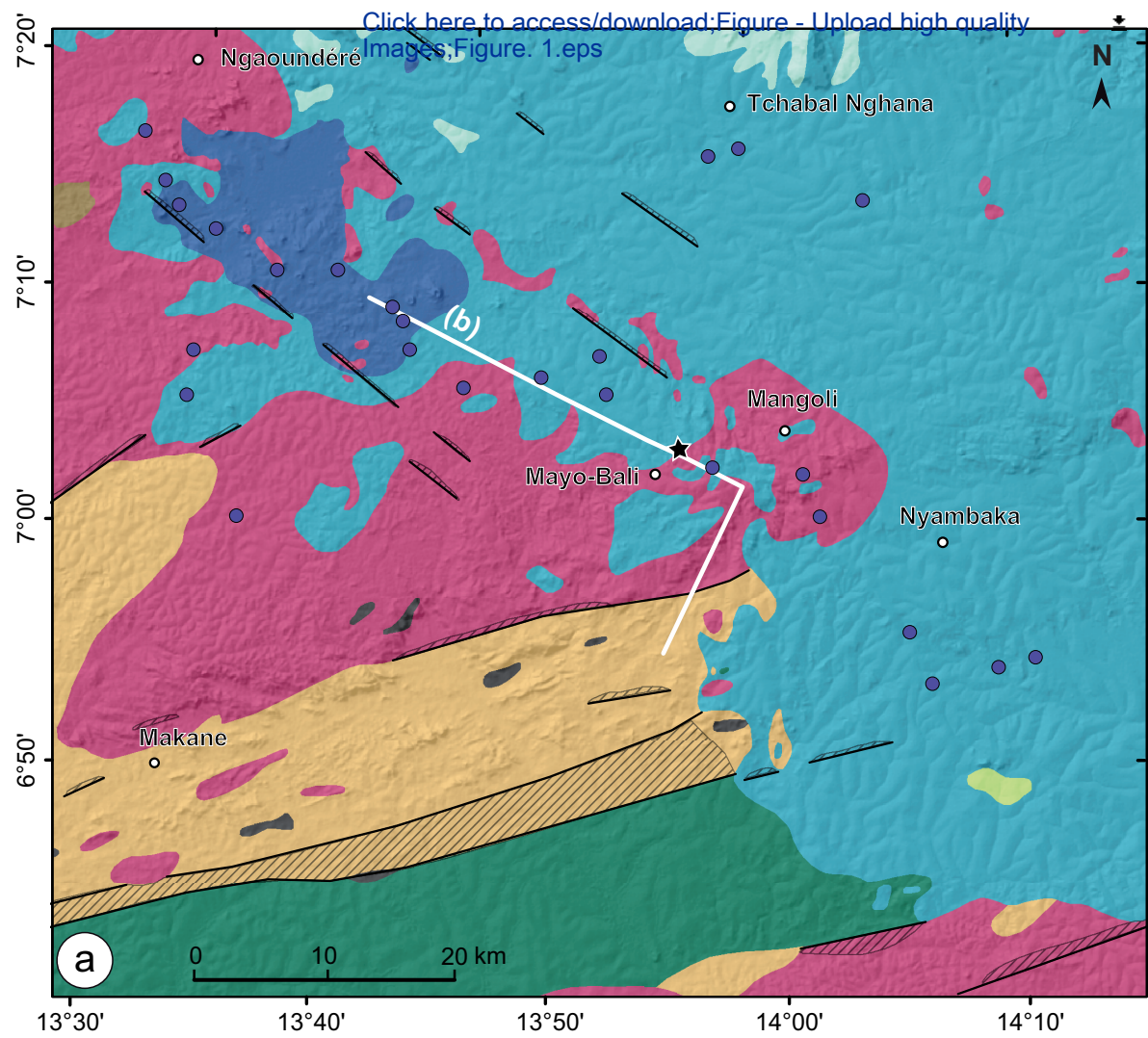
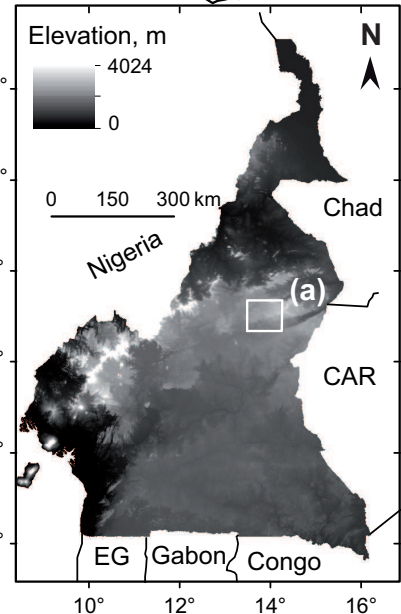
$$610 \text{Ce/Ce}^* = (\text{Ce}_{\text{sample}}/\text{Ce}_{\text{chondrite}})/(\text{La}_{\text{sample}}/\text{La}_{\text{chondrite}})^{1/2} (\text{Pr}_{\text{sample}}/\text{Pr}_{\text{chondrite}})^{1/2}$$

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

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

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

614



(b)

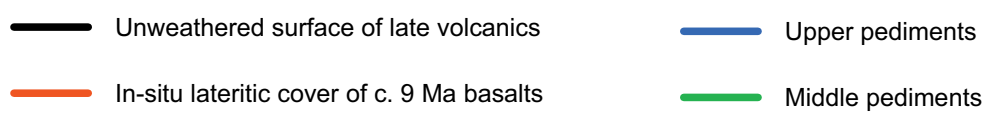


Fig. 1



Fig. 2

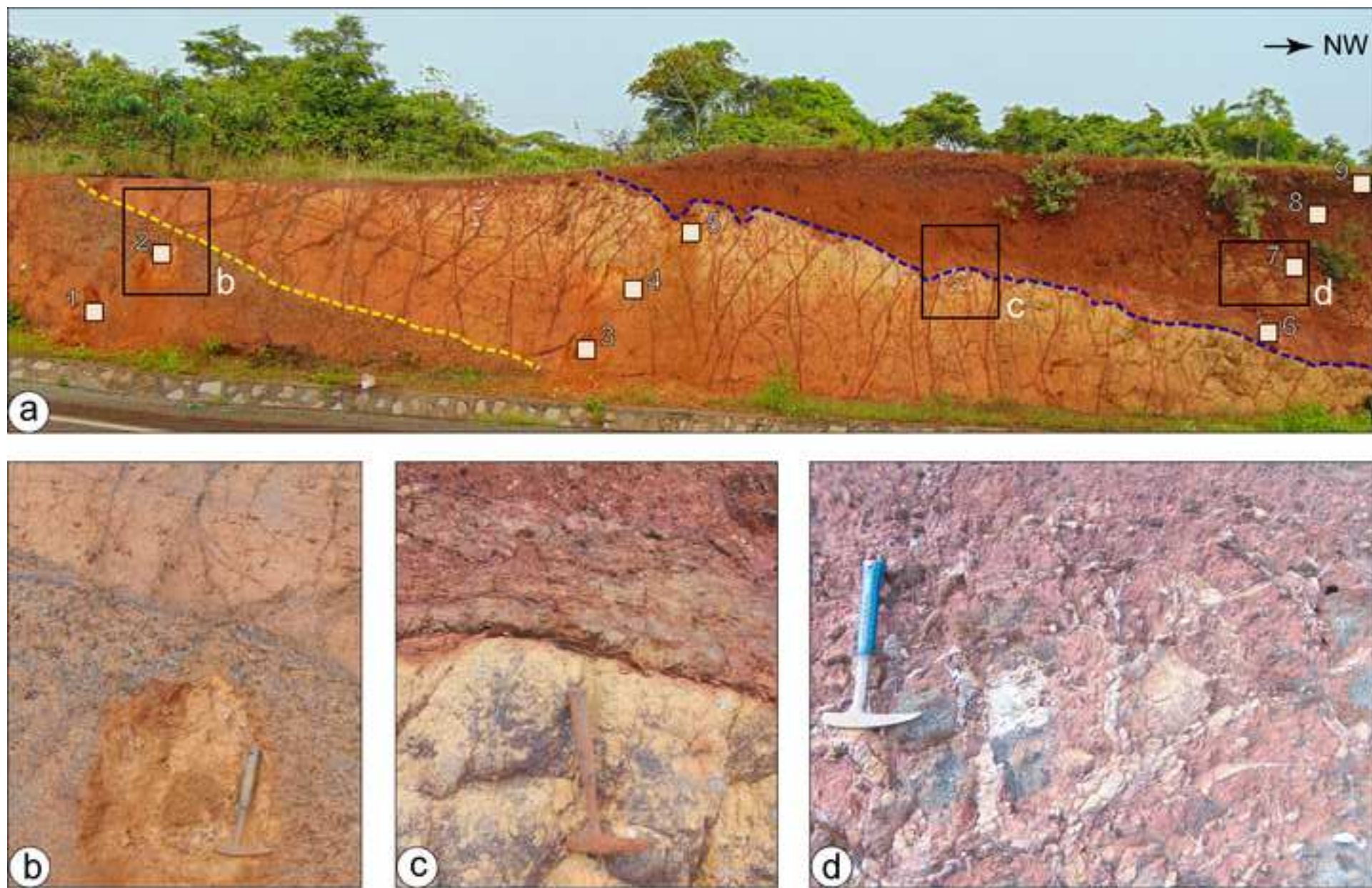


Fig. 3

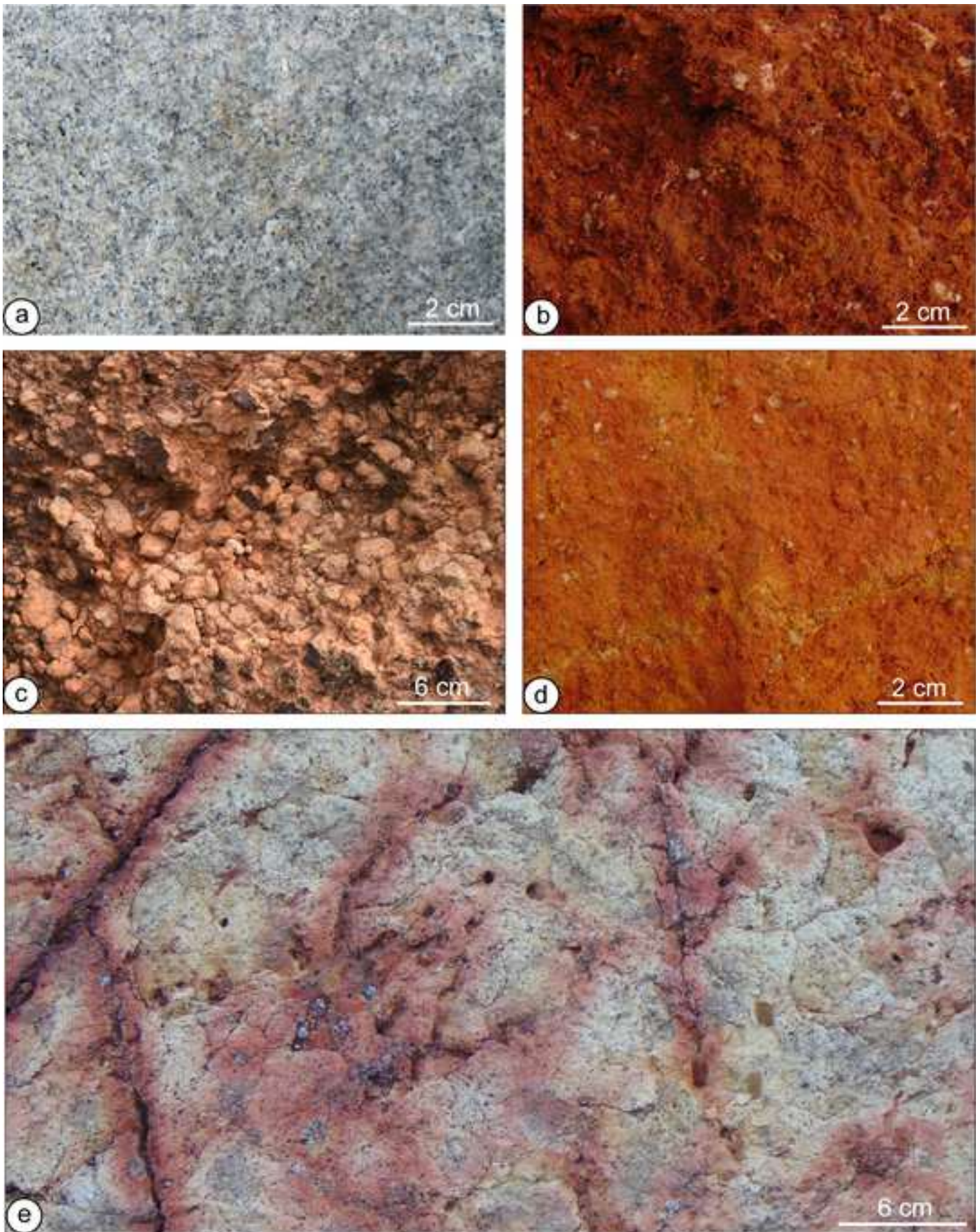


Fig. 4

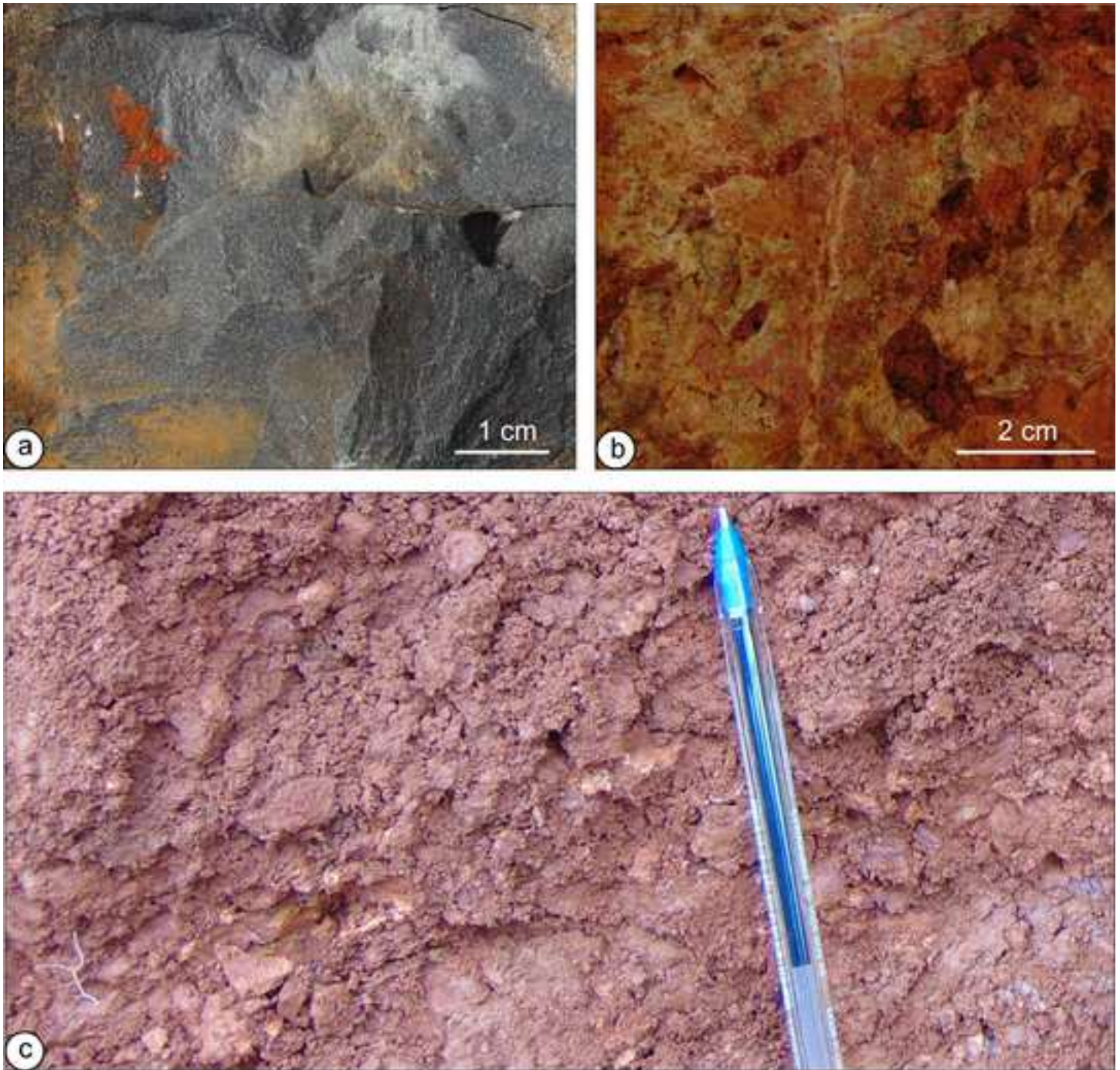


Fig. 5



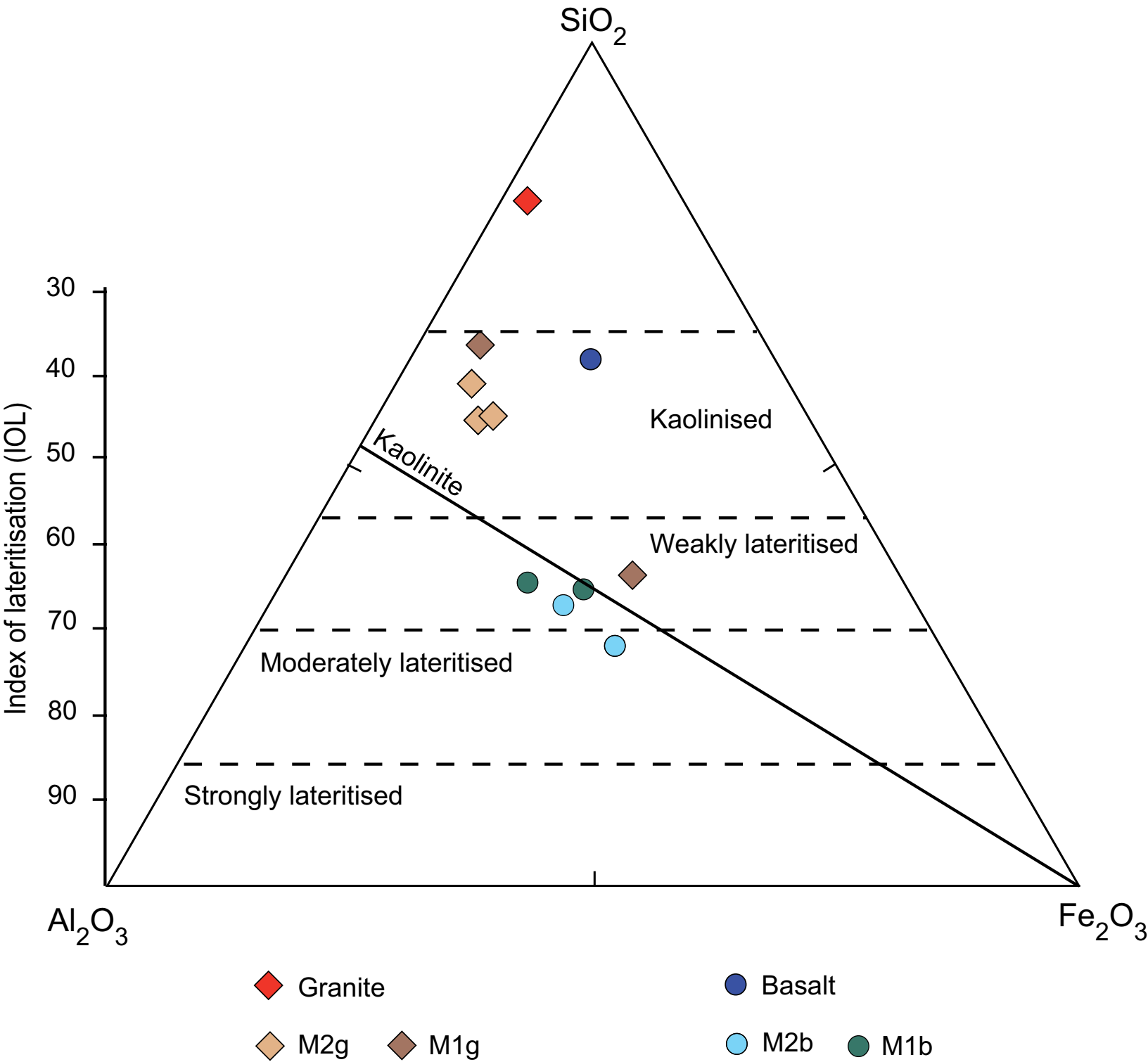


Fig. 6

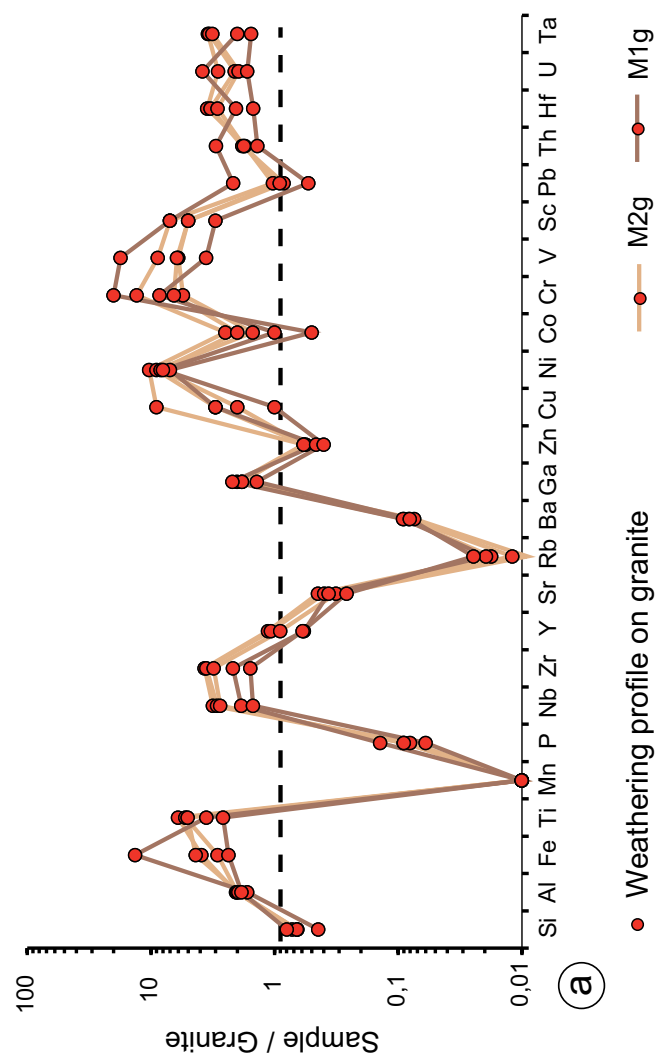
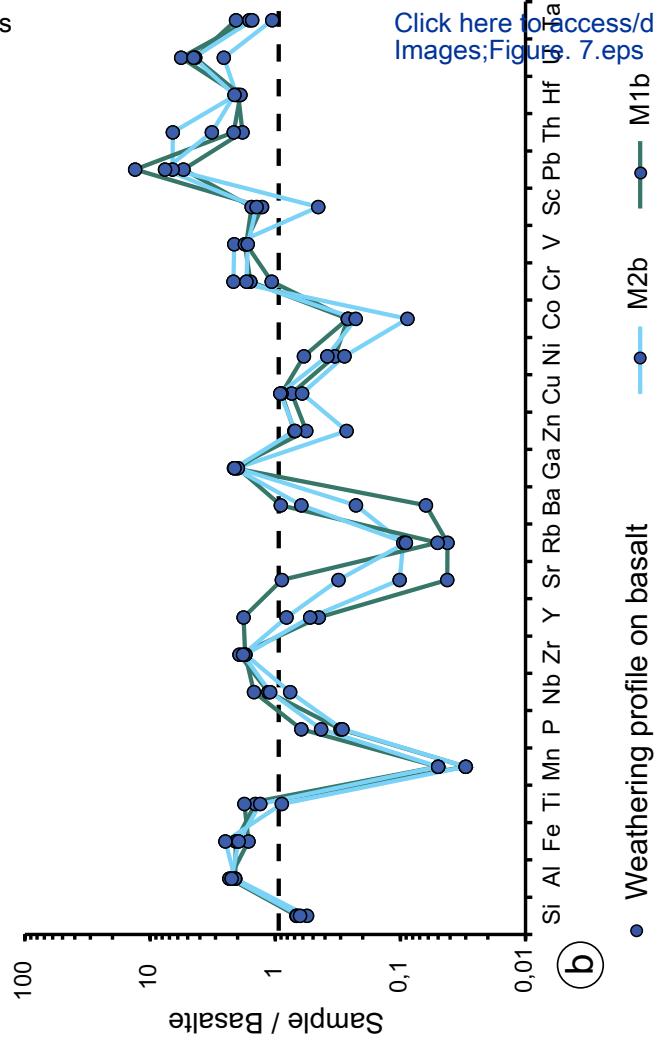


Fig. 7

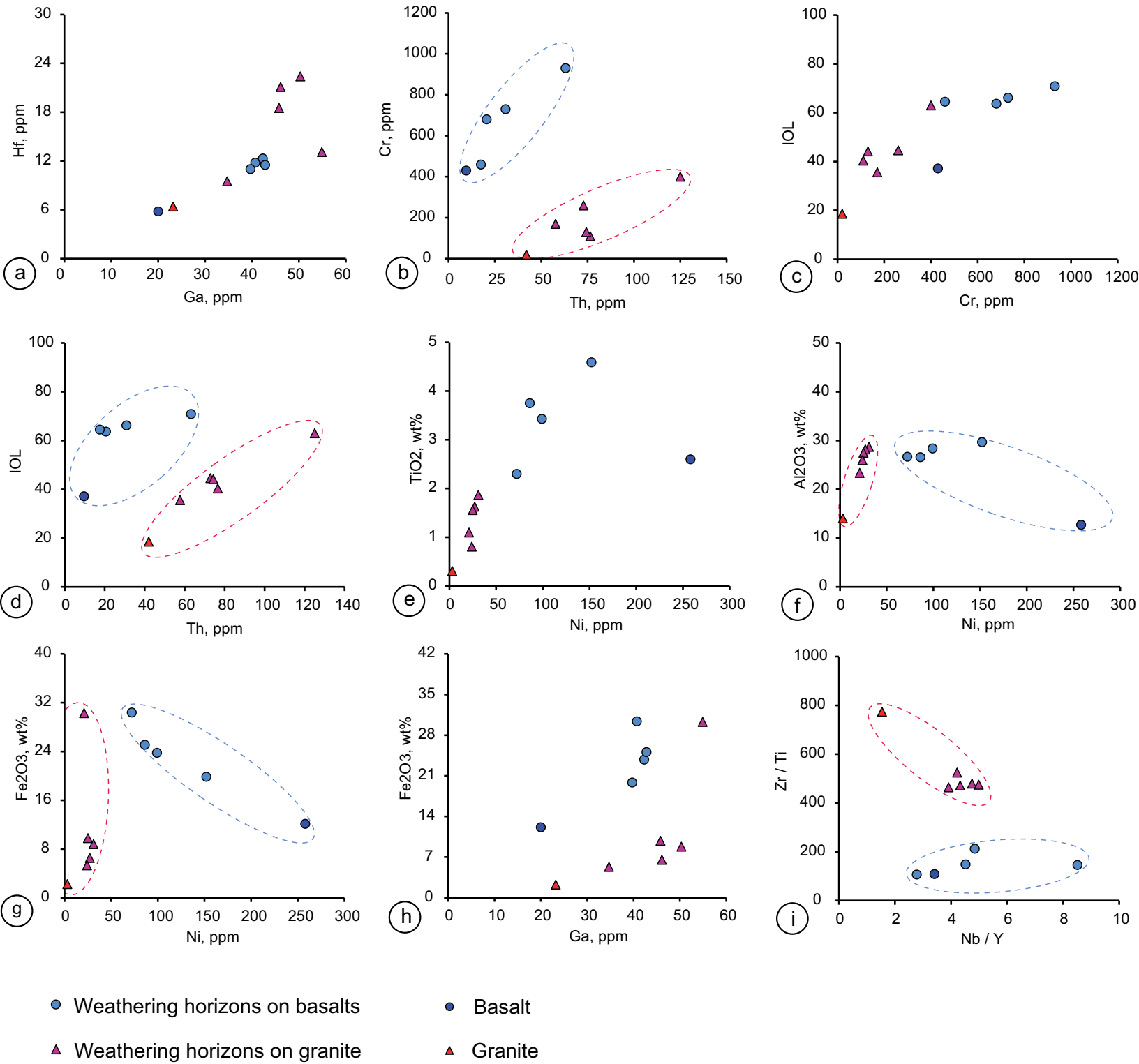


Fig. 8

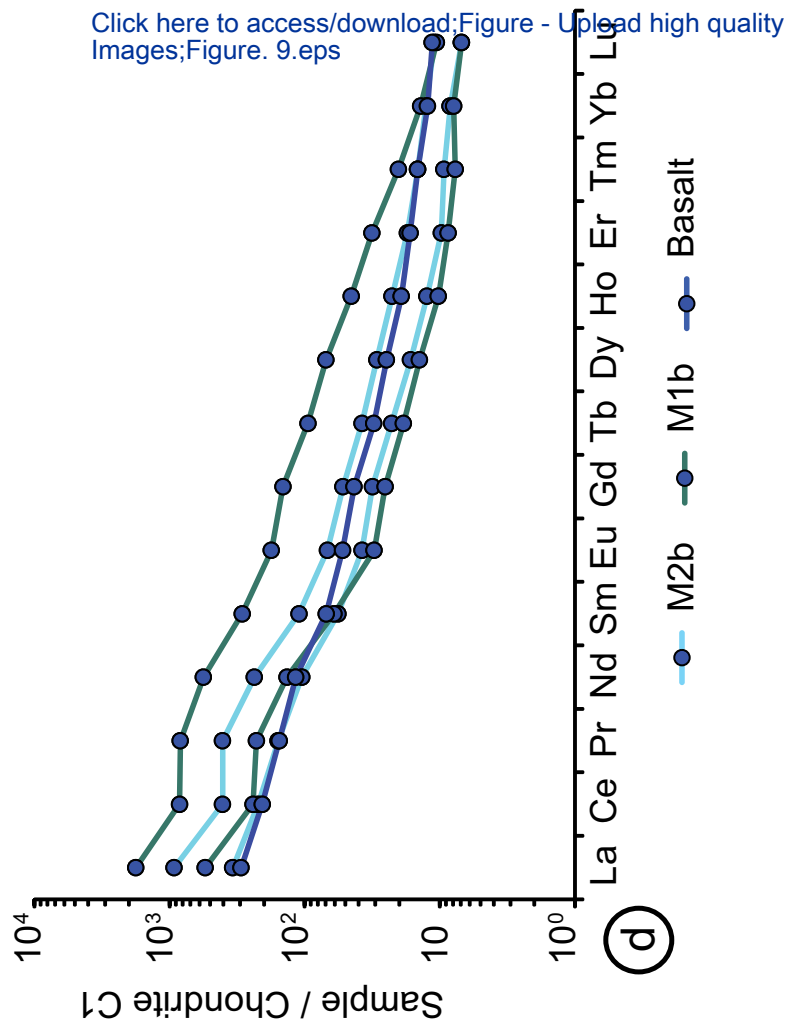
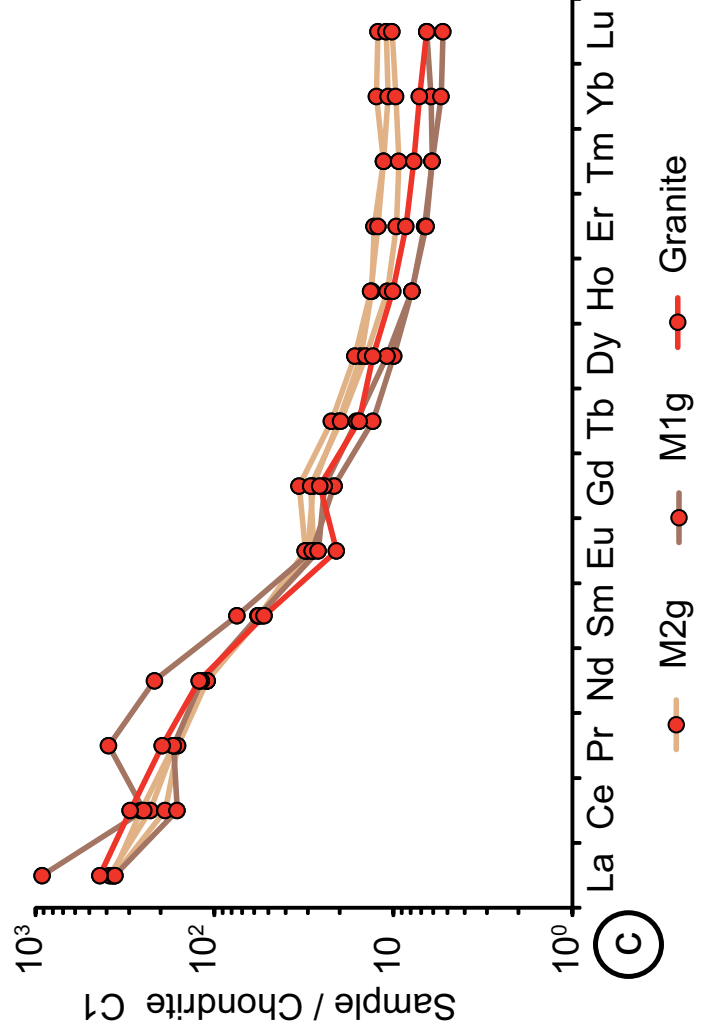
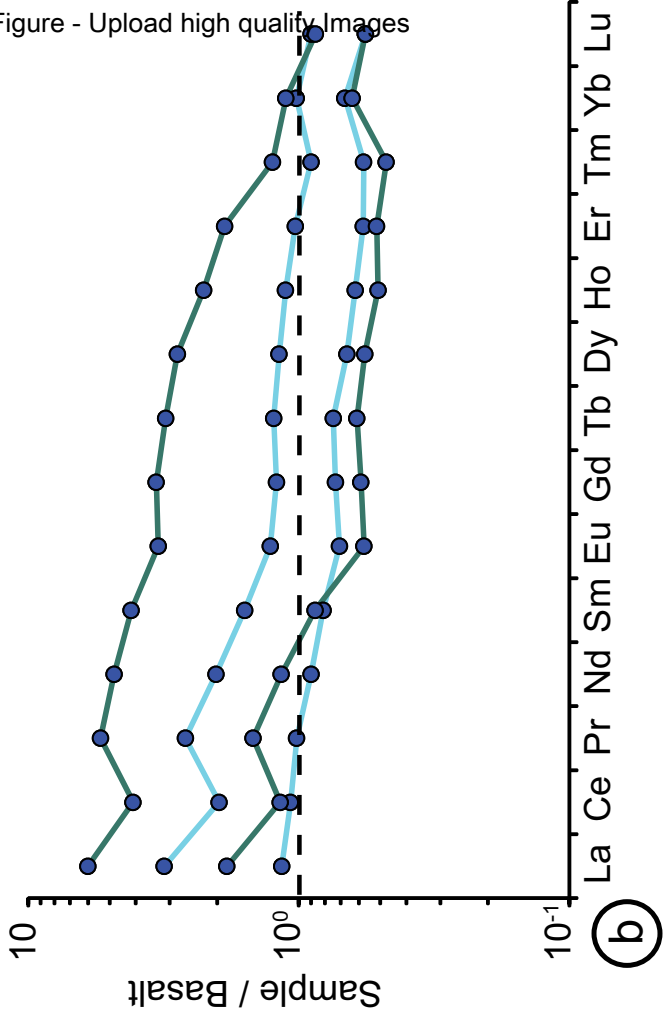
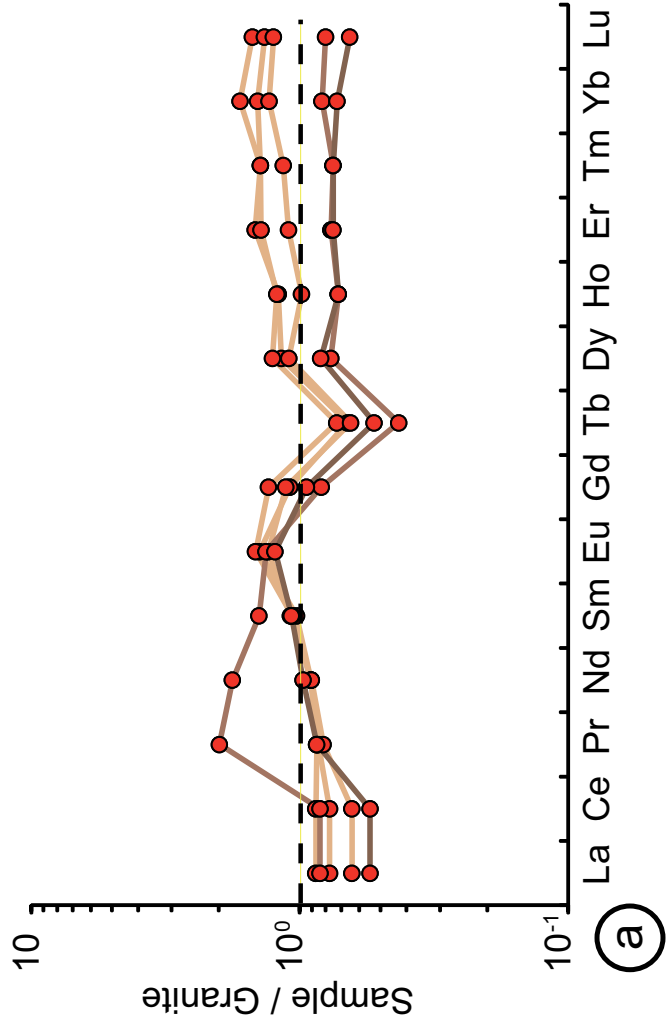
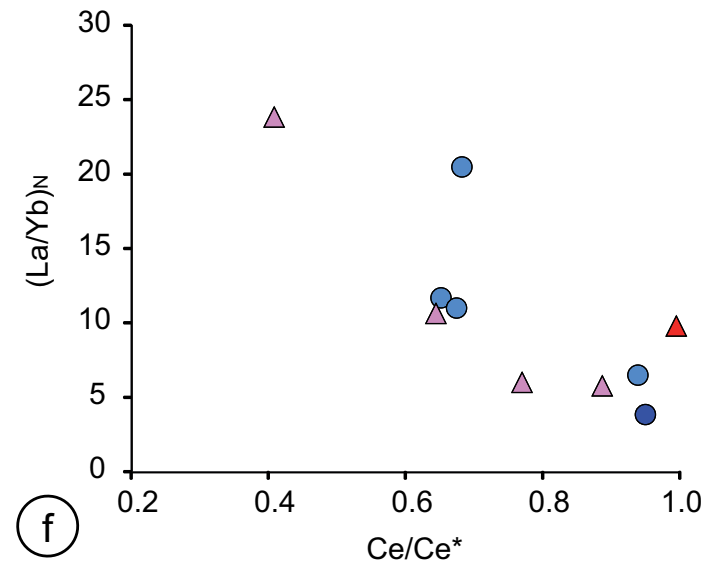
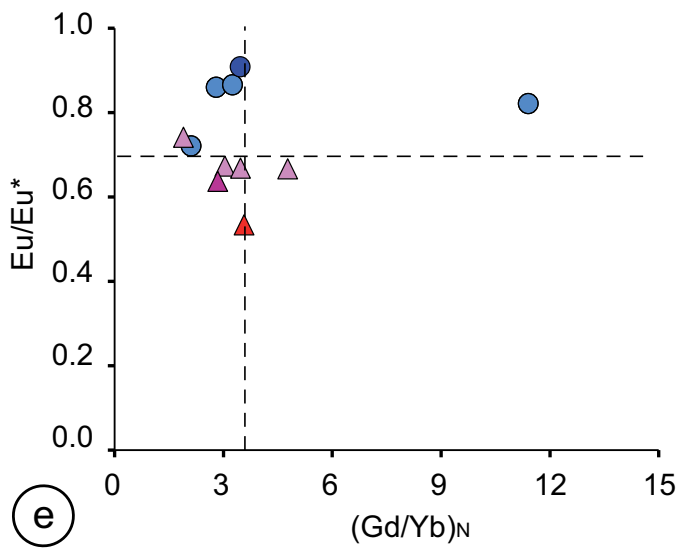
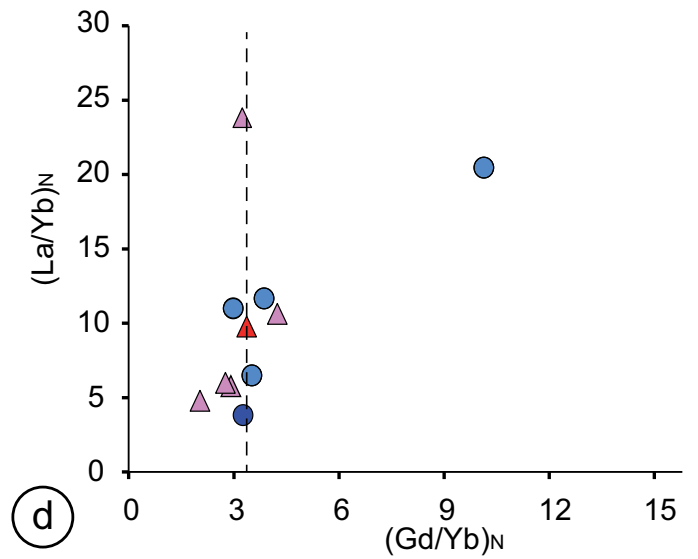
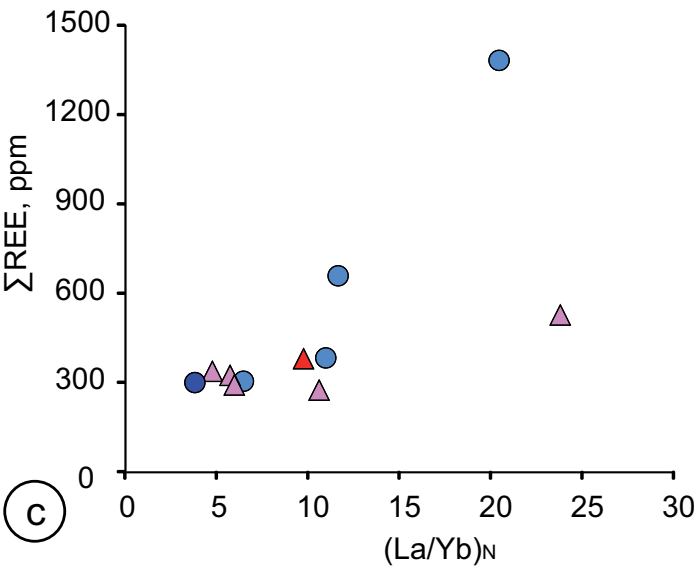
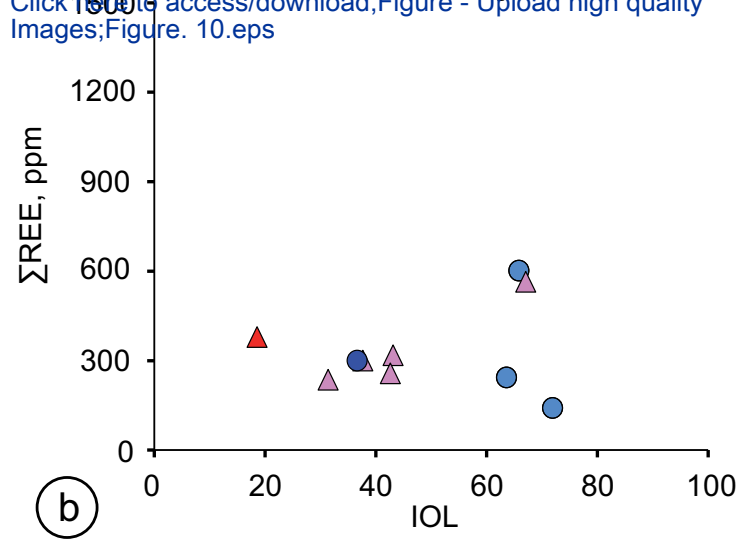
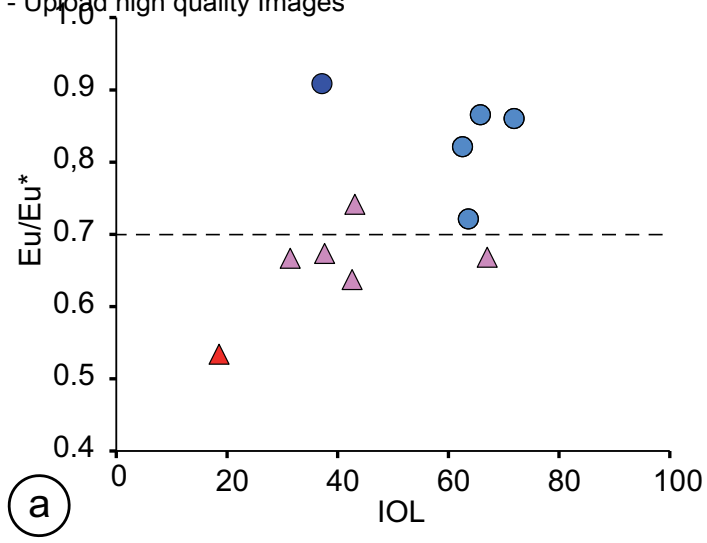


Fig. 9



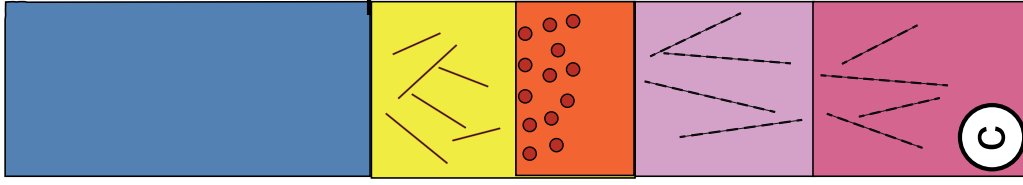
△ Weathering horizons on granite  
 ▲ Granites

● Weathering horizons on basalts  
 ● Basalts

Fig. 10

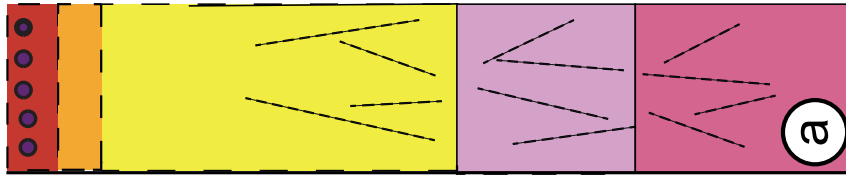
Post-Miocene, 11 Ma to modern landscape

Stage 3

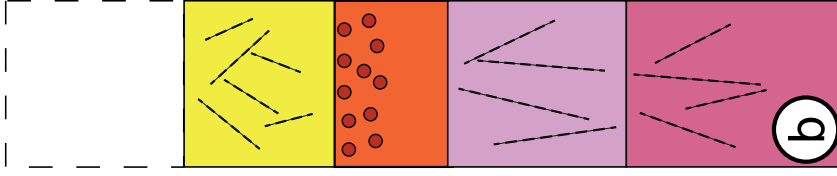


Pre-Miocene

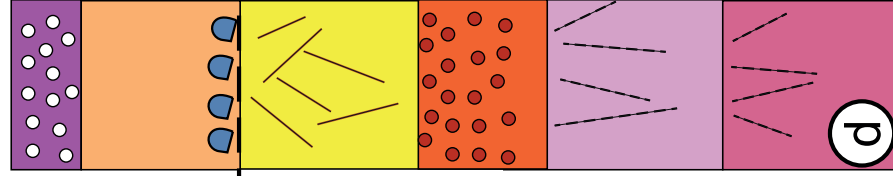
Stage 1



Stage 2



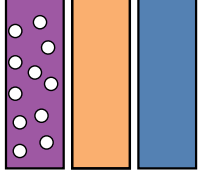
Stage 4



~ 5 m

~ 7 m

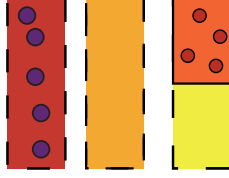
Pebbly ferruginous  
Mottled clays  
Basalt



lithological unconformity



Nodular ferricrete  
Ferruginous carapace  
Mottled clays &  
Fe/nodular horizon



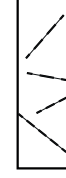
Saprolite



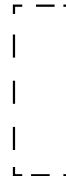
Granite



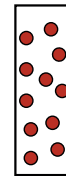
Fracturation



Eroded



In-situ Fe-nodules formation



Fe-coated fractures



(d)

(c)

(b)

(a)

Fig. 11

Table 1

Samples ID	Horizon ID	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	TiO <sub>2</sub>	CaO	MgO	Na <sub>2</sub> O	K <sub>2</sub> O	MnO	P <sub>2</sub> O <sub>5</sub>	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

		Nb	Zr	Y	Sr	Rb	Ba	Ga	Zn	Cu	Ni	Co	Cr	V	As	Sc	Pb	Th	Hf	U	Ta
Samples	Horizon ID	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) <sub>N</sub>	(Gd/Yb) <sub>N</sub>
			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