Original Research Article

OCCURRENCE OF HARDENED MATTERS IN THE ANDOSOLIC COVER FROM THE WESTERN HIGHLANDS OF CAMEROON: CASE STUDY OF THOSE RISEN ON TRACHYTE IN THE SOUTHERN SIDE OF THE BAMBOUTO MOUNTAINS

ABSTRACT

The acquisition of knowledge on hardened matters help to manage exogenous mine ore deposit. For that purpuse, petrographic, mineralogical, and geochemical characteristics of breastplate developed within Andosolic cover from Bambouto Mountains were highlighted in order to understand their genesis, organization, composition and evolution. Field work and lab analyses helped to reach the focuses. These matters have low thickness, are highly hardened, with different aspects and locations. They are present within the soils, at the point of emergence of streams, on the flatty areas on top of hills and at the foot of interfluves. They include a lithorelictuel and a vitreous facies. Microscopically, their plasmas are respectively isotic and cristic. Gibbsite, goethite, and halloysite are respectively their main minerals. Geochemically, both facies are highly aluminous. The following characteristics make them to be simply bauxitic hardened matters.

Key words: Lithorelictual, vitreous, facies, breastplate, transformation.

1. INTRODUCTION

Hardened matters are pedological masses appearing in particular environmental conditions [1]. They can be discontinuous or continuous hardpans [2]. Globally, they are often observed in tropical areas, characterized by a warm and wet type of climate [3]. Their nature is determined by their mineralogical and geochemical composition. They occur in pedological covers when the parent rocks have undergone an intense alteration, capable to generate the leaching, complete for alkali and earth alkali, and quite complete for silicon, alongside with the relative concentration of metals such as aluminum, iron, nickel, titanium among others [4]. This implies then their occurrence within soils formed after a long pedogenesis process such as soils with ferrallitic characteristics [5]. This process is then logically recurrent in zones with granite-gneissic rocks as substratum [6]. However, in volcanic regions, the formation of these matters was recently discovered [7]. They were described to be mainly gibbsitic duricrust according to their high content in aluminium. [8] showed that in volcanic environments, they can occur in different topographic positions. Implementing that observations, [9] discovered that even in andosolic soils, these matter can be present if the parent rocks of these soils are sufficiently old, and if the climate is favorable. But, the previous studies on these matters from volcanic regions didn't insist on the details of the distribution of these matters in the andosolic landscape as same as the different facies in which they appear in those particular environments. The aim of the present study is then to make clearer those aspects. For that purpose, andosolic soils risen from trachyte in the Western Highlands of Cameroon [10] were choosen.

2. MATERIALS AND METHODS

2.1 MATERIALS

The volcanic Bambouto massif is located in the Cameroonian Western Highlands, between $5^{0}25'$ and $5^{0}45'$ of North latitude, and between $10^{0}00'$ and $10^{0}15'$ of East longitude. It is a huge volcanic shield, reaching 2740m high at the summit of Mélétan Mount.

Concerning the geomorphological aspects of the present massif, three main zones characterized by some particular environmental conditions can be distinguished; these include: the upper zone, with altitudes higher than 2000m, the mid zone, with altitudes ranging between 1600 and 2000m, and the lowest zone, with altitudes ranging between 1400 and 1600m ([11], [8]). The upper zone shows an aggressive relief. Its climate is foggy and cold, with temperatures ranging between 10 and 13^{0}C. The rains are orographic type, with annual average pluviometry of 2600mm ([12], [13]). The flora is natural and anthropic. The natural part is essentially made of graze, locally disturbed by gallery forests along water course [14]; the anthropic part is made of different crops ([15], [10]).The hydrographic network is radial and dense. Soils are mostly Typical Dystrandepts [16]. Many signs of anthropic activities are present ([16], [9]). The mid zone shows a subequatorial type of climate highly modified by the altitude [17]; it is cold and wet, with nine month of rains, from march to november, and a short dry season, from december to february; the average annual temperature is about 18^{0}C; the annual average pluviometry is 1690mm. Compared to the upper zone, the relief here is less aggressive. The vegetation is mainly anthropic [15], with locally some islets of the natural vegetation in the swamps. The hydrographic network is subdendritic. Soils are mostly andic ferallitic [14]. The lowest zone finally is governed by a hot and wet climate, with an annual average temperature of 23,5^{0}C and an average annual pluviometry of 1750mm. The relief is undulating. The vegetation is quite essentially anthropic [15]. The hydrographic network is subdendritic. Soils are mainly ferallitic with hardpan within [14].

Geologically, trachytes are the major rocks in the whole massif ([18], [19]). There are also few outcrops of basalts, phonolites, rhyolites, and pyroclastites. The substratum is made of granitic and gneissic types of rocks. This substratum mainly outcrops in the lowest zone of the massif.

The pedological cover is made of andic ferallitic, desaturated, humic and strongly rejuvenated soils [9].

The hardened matters studied here are located in the upper zone of the massif [9]. The parent rock is an alcaline trachyte [9] form Miocene ([18], [19]).

2.2 METHODS

The work of [9] has helped to locate breastplate in the upper part of the Bambouto Mounts. Moreover, a deep focus on these matters have helped to subdivide them in two main facies. A careful description of the matters from the different facies help to reveal their particularities.

Their description was facilitated by wells, outcropping, and road sides. Descriptions focused also on trachytes outcropping, as well as on rocky blocks present at the soil surface. Rock and breastplate samples were finally collected for lab analysis.

In the laboratory, three major analysis were carried out, notably microscopicic, mineralogical, and geochemical ones. Microscopicic analysis consisted in the study of the slides of rock and breastplate under polarizing compound microscope. Slides were built up in the petrography laboratory of IRAD, Nkolbison (Yaoundé). Mineralogical and geochemical analysis, proceeded respectively by X-ray diffractometry on a device using cupper anode and by fluorescence, were made on total breastplate and rock powder in the Mineral Analysis Centre of Lausanne University, Switzerland.

3. RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Morphology of the site of the studies

The site of the study is located on the south-east border of the Bambouto Mountains caldera, in the Meletan locality. Its relief is rough, characterized by the presence of many interfluves with step sides. They are principally flow-like trachytic domes, with flatty summits. They are circumscribed by water courses or by escarpments.

3.1.2 Petrographic study of the parent rock

The parent rock is a trachyte. It outcops at the summit or on the sides of interfluves as blocks with variable sizes. It is dark grey, massive, hard with a saccharoid aspect, compact, more or less altered, traversed by many diaclasis with tanned borders. On the altered zones appearing, many phenocrist of sanidine more or less weathered are easily recognized, conferring to the rock a mangy aspect.

The observation of a slide of the rock under compound microscope reveals the presence of many phenocrysts of sanidine and few quantities of pyroxene and dense minerals drown in a matrix essentially made of microcrysts of sanidine (figure 1). Dense minerals represent about 5% of the whole rock. They have sizes ranging between 0.5 and 1mm; they are both present in the matrix and as inclusions in phenocrysts of sanidine; they are ilménite, magnetite, and apatite according to X-ray diffraction.

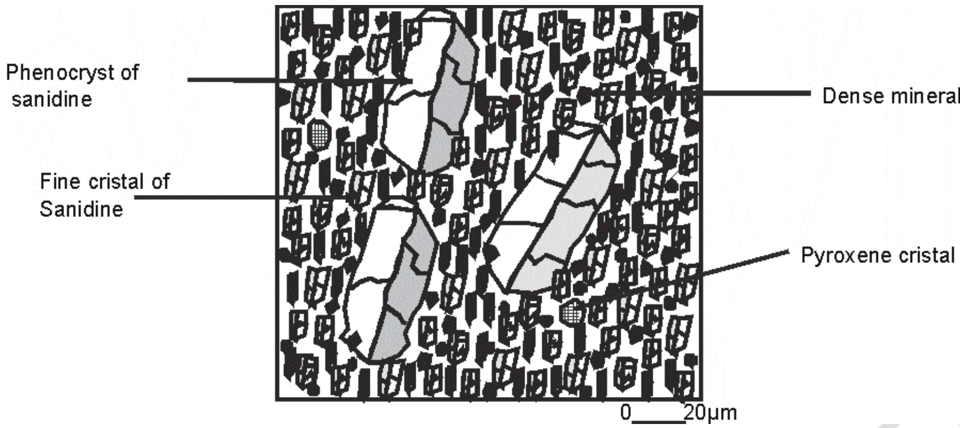

Figure 1 : Microscopic organization of the trachyte of Meletan

Geochemical analysis of the rock shows that silicon is the most abundant element (58.00%SiO_2), followed by (18.40%Al_2O_3) and iron respectively (5.63%Fe_2O_3). Alkali are abundant (6.56%Na_2O for the sodium and 5.23%K_2O for the potassium) compared to earth alkali elements (2.10%CaO for the calcium and 0.41%MgO for the magnesium). Titanium (0.44%TiO_2), manganese (0.30%MnO), and phosphorous (0.14%P_2O_5) are also present (table 1). After the binary diagram (Na_2O+K_2O)/SiO_2 of Le Maître (1989 *in* Tamen, 1994), the present rock is an **alkaline trachyte**.

Table 1 : Chemical composition of the mother rock

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	MgO	CaO	Na_2O	MnO	P_2O_5	H_2O	Total
Mother rock	58.00	18.40	5.63	0.44	5.23	0.41	2.10	6.56	0.30	0.14	2.01	99.22

3.1.4 The hardened matters

3.1.4.1 Location in the landscape

In the landscape, hardened matters appear at different levels. They are present along the interfluves or in the flatty zones at their summit and foot.

In the interfluves, they appear as continuous hardpan; they appear also as individuals with variable sizes. They are present on the summital projecting shelf, at the zones of occurrence of streams, on the sides, in the cracks of rock and isalteritic masses, and in the pedoturbated matters where they are lined in the continuity of cracks from the parent rock; they are also observed as complete horizons.

On the projecting shelf at the foot of the interfluves, they mainly appear as continuous hardpan, and locally as juxtaposed individuals. At the zones of occurrence of streams, they are mainly continuous hardpans.

Globally, they appear with isalteritic rough aspect or with smooth and vitreous aspect; this helps to define here two different facies: the first one is flatty with rough aspect and the second one is smooth with vitreous aspect. The facies with smooth and vitreous aspect is only present in the cracks and in the horizons with hardened matters. In the horizon with hardened matters, the matters with the flatty and rough facies wrap up the matters with smooth and vitreous aspect. The facies with the flatty and rough aspect is the most abundant one. From uphill to downhill, these hardened matters independently to their facies present morphologic variations.

3.1.4.2 Morphology

3.1.4.2.1 The lithorelictual facies

On the uphill position, matters can reach 7 to 10cm in average length. They are flatty with a rough surface. Their back ground is highly hardened and light grey (10YR8/2) to dark pale yellow (2.5Y8/4). It drowns millimetric white (10YR8/1) and reddish (7.5YR6/6) domains, beside which there are brown to dark borders (7.5YR3/2). The white domains (10YR8/2) are roundish with distinct borders; the reddish domains (7.5YR6/6) have uncertain shapes and doubtful boundary with the light grey (10YR8/2) to dark yellow pale (2.5Y8/4) back ground. In the same back ground, one can locally find many greyish (10YR7/3) phantoms of sanidine with stick-like shape and clear orientation, recalling those of the rock. Some holes with irregular contours and some pockets fill with yellow (2.5Y8/4) or reddish (7.5YR6/6), hardened, and silty matters are also present.

On the downhill position, some morphological variations appear. The yellow matters appear as large domains with clear contours across the hardened blocks. They are floury, abundant and more or less dense. Reddish (2.5YR7/1) and dark reddish brown (2.5YR5/4) highly hardened islets with clear contours appear in equivalent proportions. They are more or less continuous and dense bands, locally partitioned by the yellow (10YR7/8) matter. The reddish (2.5YR7/1) and dark reddish brown (2.5YR5/4) domains are sometimes observed as local spots within the yellow domain. The white (10YR8/2) domain is present. It is few, hardened, with clear contours. They are essentially millimetric (7mm for the longest), stick-like, and oriented islets. Locally, they bear yellowish (10YR7/8) and more or less hardened spots. All the domains mentioned are traversed by many millimetric cavities.

3.1.4.2.2 The vitreous facies

The vitreous facies is represented by hardened, centimetric (up to 20cm), and paving stone-like blocks with smooth surface. They are disseminated in the flatty with rough surface blocks. They are reddish (7.5YR6/6), locally translucent (vitreous aspect), massive, compact, highly hardened, and larger than the blocks of the flatty and rough surface facies. Some roundish cavities are disseminated all over their surface. The translucent matrix of these matters are locally blurred by brown (7.5YR3/2) and reddish (7.5YR6/6) frameworks. The reddish (7.5YR6/6) frameworks are fewer and denser than the brown (7.5YR3/2) frameworks. Some whitish (10YR8/2), brownish (7.5YR3/2) and sometimes reddish (7.5YR6/6) sticky-like domains are present. Some rare roundish yellowish (10YR7/8) domains are also present.

On the downhill position, the size of the blocks decreases (about 4cm in average) while their induration degree increases. Four hardened domains are present: yellowish (10YR7/8), red (10R4/8), brown (2.5YR5/6 to 2.5YR5/4), and white (10YR8/1). The yellowish domain (10YR7/8) is the most abundant. It is fairly dense and constitutes large bands. The red domain (10R4/8) is made of islets with irregular shape and clear contours, drowned in the yellowish (10YR7/8) domain. The brown domain (2.5YR5/6, 2.5YR5/4 to 2.5YR2/1) constitutes a framework with clear boundaries at the surface of the yellowish domain (10YR7/8). The white domains (10YR8/1) are especially millimetric roundish islets, with diffuse contours, disseminated towards the edges of the yellowish (10YR7/8) domain.

At the intermediate part of the interfluves sides, one can observe some particular paving stone-like blocks with vitreous but non translucent aspect. Their central portions are red (10R4/8) and their borders are whitish (10YR8/2) to light reddish (10R4/6). This organization keeps them closer to the blocks of the present facies.

3.1.4.3 Micromorphology

The study of the slide of the hardened matters under compound light microscope reveals three different matrix: a light grey matrix, a dark matrix, and a red matrix (figure 2).

The light grey matrix is the most abundant (70% of the slide). Its plasma is light grey, abundant (80% of the matrix), dense, highly birefringent, with a cristic structure. The skeleton is heterogeneous and fairly abundant (25% of the whole matrix). The primary skeleton is made of dense mineral; it represent about 10% of the whole skeleton; the individuals of the present skeleton are spherical and dense, with an average diameter of about 600µm; their contours are clear and their relief is high; they recall those observed in the rock. The secondary skeleton is made of phantoms of phenocryst of sanidine completely pseudomorphosed by a highly birefringent cristic gibbsitic plasma; it is abundant (90% of the whole skeleton); the individuals of the present skeleton have about 4mm length and 1mm width in average; they are stick-like, with the same orientation; they recall the phenocrysts of sanidine observed in the rock. Some holes are present (10% of the matrix). They are mostly elongated; their borders are locally covered by a dark and a red weekly brefringent plasma, both isotic.

The dark matrix is few (20% of the slide) and disseminated in the slide. The plasma is dark, abundant (95% of the matrix), dense, and isotic; it is a framework nascent at the borders of the holes and covers partially the phantoms of sanidne. The skeleton is homogenous and principally represented by phantoms of sanidine completely pseudomorphosed by a highly birefringent cristic gibbsitic plasma. Holes are principally fissures edging the matrix.

The red matrix is fewer (10% of the slide). It is a framework with finger-like shape. The plasma is red, abundant (95% of the matrix), dense, and isotic ; it is bordered in one side by the holes, and in other side by phantoms of sanidine that it covers sometimes. The skeleton is homogenous and principally represented by phantoms of sanidine completely pseudomorphosed by a highly birefringent cristic gibbsitic plasma. Holes are principally fissures edging the matrix.

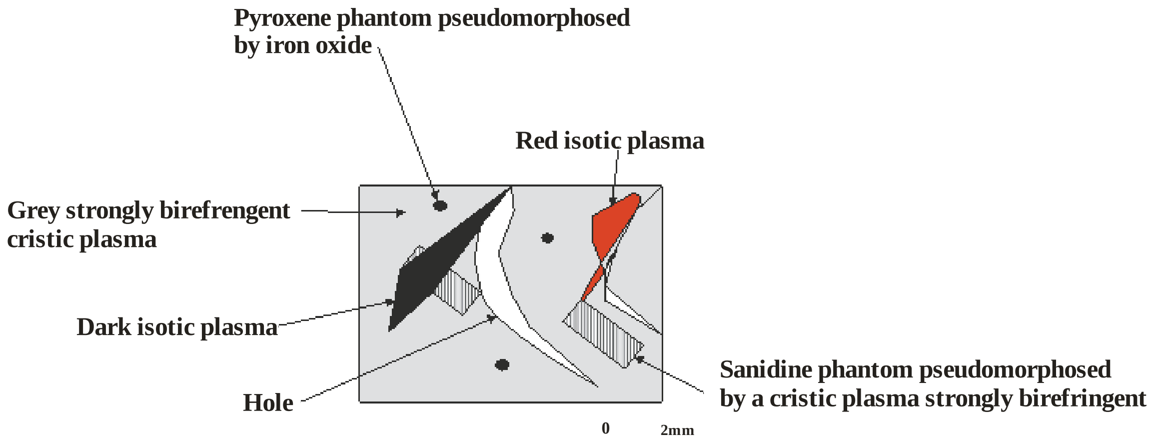

Figure 2: Microscopic organization of the hardened matters

3.1.4.4 Geochemistry and Mineralogy

Geochemically, the hardened matters have high concentrations of aluminum (55.88%Al_2O_3) and enough concentrations of iron (11.68%Fe_2O_3); the silicon is quite absent (2.88%SiO_2). Alkali and earth alkali are absent or weekly detected. Titanium (0.74%), phosphorous (0.53%), and manganese (0.27%) are the other elements. Water occupies 26.82% of the whole matter (table 2). Gibbsite, goethite, and halloysite are respectively the principal minerals of these matters.

Table 2 : Chemical composition of the hardened matters (%)

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	K_2O	MgO	CaO	Na_2O	MnO	P_2O_5	H_2O	Total
Hardened matters	2.88	55.88	11.68	0.74	0.06	0.15	0.01	0.00	0.27	0.53	26.82	99.02

3.2 Discussion

The upper part of the Bambouto Mount is made of many flow-like domes with abrupt sides, bordering deep valleys; this is the particularity of plateau landscape [11]. The climate is equatorial of Cameroonian subtype [13]; it is the characteristic of environments where allitisation predominates [8]. The rock is of felsic type [19]; its richness in sanidine [9], coupled to the highly wet climate is a token of bauxitisation [21]. The presence of horizons with hardened matters in the andosolic cover agrees with the existence in the upper part of the Bambouto Mountains of hardpan at different topographic position. Their presence testimonies the bauxitisation phenomenon occurring elsewhere in the volcanic line of Cameroon as described by [22], [2], [7], and [8].

3.2.1 The lithorelictual facies

[23] demonstrated that during the lavas flow, this magmatic fluid is organized in superposed layers. These bands isolate among them discontinuities, which are the

openings through which water and other solutions that can attack the rock flow [24]. So, during the alteration, the layers are dislocated into isalteritic blocks with variable sizes, which will finally fossilized the flatty shape of the layers of the lavas. Under the compound light microscope, intense pseudomorphosis process is observed within those isalteritic blocks [9]. This contributes to maintain the organization of the rock [25] and to increase its hardness [9]. Moreover, at the same time, some locations of those isalteritic blocks in transformation are reddened and tanned, with isoctic plasmic structure [9]. This implies the contribution of iron among other in the hardening process of the isalteritic blocks; this corroborates the high degree of hardness of those matters as observed on the field. Great quantities of aluminum are detected in those blocks; this observation is the testimony of the fact that they have aluminous characteristics. Gibbsite is their main mineral; this corroborates their high concentration in aluminum. So, their high hardness makes them hardened matters ([6], [26]). The high concentration of aluminum and gibbsite in those hardened matters brings them closer to aluminous hardened matters. According to [25] and [27], they can be said to be lithorelictuel hardened matters. The studies of [21] and [8] are openings allowing us to consider those matters as bauxitic matters. The rock outcropping are characterized by the presence on their surface of many phenocrysts of sanidine [9]. The conservation of the rock structure in the isalteritic blocks and further in those bauxitic matters contribute to create lithorelictuel facies, characterized by the flatty shape and the rough surface of the blocks.

3.2.2 The vitreous facies

The diaclasis of the isalteritic blocks on the uphill position and on the intermediate position are filled with a hardened matter characterized by its smooth surface, vitreous aspect, with a break in conchoidal marner. In fact, within the discontinuities of the rock and isalteritic blocks, water filled with ions moves [24]. When the saturation point of each ion is reached in the water percolating within the cracks, the process of precipitation starts, producing secondary crystallized matters [28] on the borders of the cracks. According to the high quantity of aluminum in the andosolic pedological cover of Bambouto Mountains [9], aluminum followed by iron are the first metals to start the precipitation. In the red and yellow horizons, hardened matters with tanned borders perfectly lined with diaclasis from rock are observed [9]. This observation agrees with the accumulation process in the cracks in one hand, and in the other hand with the implication of those diaclasis in the transfer of ions through water flowing across the pedological cover. In addition, that observation implies also the lateral and vertical migration of aluminum in the andosolic pedological cover of the Bambouto Mounts ([1], [29], [30], [31], [3], [32]). The vitreous hardened matters deposited in the cracks resemble the paving stone-like matters with smooth surface blocks present in the hardened horizons [9]; we can then think that a genetic link exists between those two matters. In the blocks constituting the vitreous facies, rare phantoms of sanidine pseudomrphosed by gibbsite are present; this can be due to the resorption of the portion of the isalteritic blocks closer to the cracks [9].

The hardened matters observed in the diaclasis are highly translucent on the uphill position compared to those observed on the downhill position. Moreover, all those matters are highly reddened and tanned on the downhill position compared to those observed on the uphill position. The reddening can be explained by the precipitation of iron on the surface of those matters; the tanning for its one can be explained by the precipitation of manganese. Under the compound light microscope, the dark matrix covers partially the red matrix; this shows that iron precipitates before manganese; this agrees with the high quantities of iron in the pedological cover compared to that of the manganese. This observations strengthen the theory of the migrations of matters within the andosolic cover of the Bambouto Mounts ([29], [32]), improved by the gravity [27]. At the point of the emergence of streams, hardpans are present; this certifies the implication of water in the development of this pedological matters. In the pedological cover, the rate of humidity increases towards downhill. This is in accordance with the reddening and the tanning phenomenon observed on the borders of hardened matters filling the diaclasis of isalteric blocks on the downhill position. The degree of induration of isalteritic blocks decreases away from the diaclasis. This is in accordance with the possibility of migration followed by the deposit of hardening substances such as aluminum and iron on the borders of cracks through water ([33], [1], [31], [32]); this corroborates the great quantity of aluminum followed a little bit far by iron detected in this pedological cover by [9]. The predominance of aluminum in this andosolic pedological cover certifies that the concerned hardening matter is principally aluminum; this corroborates the great quantity of rain falls in this environment, necessary to generate bauxitic weathering ([34], [21], [35]). The presence of two levels of hardened horizons on the downhill position testimonies a high degree of accumulation of matters in that direction [9]. In the isalteritic horizon, isalteritic blocks are the most abundant compared to the vitreous hardened matters deposited in the cracks. At the end of the evolution of those two different matters, this original organization is maintained. This is then why the hardened blocks of the rough facies wraps up the hardened blocks of the paving stone-like with smooth facies. During the transformation of the hardened matters deposited in the cracks into the paving stone-like blocks found in the hardened horizons, the smooth aspect of their surface is maintained [9]; this contributes to create the vitreous facies.

4. CONCLUSION

The aim of the present study was to highlight the occurring of hardened matters in the andosolic cover of Bambouto Mounts. So, petrographic, mineralogical, and geochemical characteristics of those breastplate were followed up in order to understand their genesis, organization, composition and evolution. These matters have low thicknesses, are highly hardened, and are mostly reddened and tanned on the downhill position. They are present within the soils, at the point of emergence of streams, on the sides and on the flatty areas on top of hills, in the diaclasis, and at the foot of interfluves. They include a lithorelictuel and a vitreous facies. Microscopically, their plasmas are cristic and locally isotic. Gibbsite, goethite and halloysite are their main minerals. Geochemically, both facies are highly aluminous. They are then bauxitic hardened matters.

COMPETING INTEREST

Authors have declared that no competing interest exist.

REFERENCES

[1]Bonneau et Souchier B. Pedology 2. Components and soil properties. Doc. 1st Ed. Masson, 1979, 459p.

[2]Eno Belinga SM. Ex ternal dynamic geology of tropical countries of the earth. Iron landscapes. Yaoundé: University Library 1983.

[3]Tsozue D., Bitom D., Lucas Y. Biogeochemistry of Iron, Aluminium and Silicon in Humid Tropical Mountainous Soils (Bambouto Mountain, West Cameroon). *The Open Geology Journal,* 2009, *3,* 70-81

[4]Temgoua E., Bitom D., Bilong P., Lucas Y., Pfeifer H. R. Démantèlement des paysages cuirassés anciens en zone forestière tropicale d'Afrique Centrale, formation d'accumulations ferrugineuses actuelles au bas des versants. C. R. Géosciences, 334, 2002, 537-543.

[5]Tematio P., Fritsch E., Hodson M.E., Lucas Y., Bitom D., Bilong P. Mineral and geochemical characterization of a leptic-aluandic soil and athapto-aluandic-ferralsol developed on trachytes in Mount Bambouto (Cameroon volcanic line). Geoderma 152., 2009, Pp 314-323.

[6] Bitom D. (1988) - Organization and evolution of a ferralitic cover in humid tropical zone (Cameroon). Genesis and transformation of deep indurated ferruginous complexes. Th. Doct., Univ. Potters, 164p.

[7]Momo Nouazi M., Tematio P., Yemefack M. Multiscale organization of the Doumbouo-Fokoue bauxites ore deposits (West Cameroon) : Implication to the land-scape lowering. Open J. Geol., 2, 2012, Pp14-24.

[8]Momo Nouazi M., Tematio P., Yemefack M. Multiscale organization of the Doumbouo-Fokoue bauxites ore deposits (West Cameroon) : Implication to the land-scape lowering. Open J. Geol., 2, 2016, Pp14-24.

[9] Fopoussi Tuebue J.C. Petrology of the Andosols of the Western Highlands of Cameroon and fertilization test: case of a toposequence developed on trachyte of the upper zone of the southern slope of the Bambouto Mountains. Doctoral thesis.

Department of Earth Sciences, Faculty of Science, University of Ngaoundere. 2018, 233p.

[10]Fopoussi Tuebue J.C., Basga S.D., Tematio P., and Nguetnkam J.P. Effect of Trachyte Powder, Human Urine and Reserved Water from Cooked beans on Andosols Fertility in Cameroonian Western Highlands. Asian Journal of Soil Science and Plants Nutrition, 3(2), 2018, 1-17

[11] Morin S. (1988) - The fundamental dissymmetries of the Highlands of Western Cameroon and their consequences on human occupation. Example of Bambouto Mountains. Man and the tropical mountain. SEPANRIT ed., Bordeaux, pp49-51.

[12] Valet S., 1985- Explanatory notes on climate maps, agro-geological landscapes and proposals for developing the agro-geological landscapes of western Cameroon 1/200 000 CIRAT-IRAT, Montpellier, 120p

[13] Tékoudjou E. (2004) - Study of rainfall variability on the southern flanks of the Bambouto Mountains. Same. D.E.A .. Univ. Ydé I, Fac. Sci. 47p.

[14]Tematio P., Kengni L., Bitom D., Hodson M., Fopoussi J.C., Leumbe O., Mpakam H.G., Tsozue D. Soils and their distribution on Bambouto volcanic mountain, West Cameroon highland, Central Africa. Art., ELSEVIER, J.A.E.S., 2004, 447-457.

[15]Tematio P. et Olson K.R. (1997)- Impact of industrialized agriculture on land in Bafou, Cameroon. J. of Soil and water conservation, Nov.-Dec., 1997, 404-405.

[16]Tematio P., Tsafack E. I., Lucas Kengni. Effects of tillage, fallow and burning on selected properties and fertility status of andosols in the Mounts Bambouto, West Cameroon. Agricultural Science. Vol. 2 no 3. 2011, 334-340

[17] Ngoufo R. (1988) - The Bambouto Mountains. Environment and use of space. Thesis Doct. 3rd cycle of geophysics. Univ. Yaoundé, Vol. 1 and 2, 374p.

[18] Tchoua F. (1974) - Contribution to the geological and petrographic study of some volcanoes of the Cameroon Line (Mount Manengouba and Mount Bambouto). Thesis Doct. State Sc., Univ. Clermont Ferrant, 347p.

[19] Youmen D. (1994) - Volcanic, Petrological and Temporal Evolution of the Bambouto Mountains Caldera (Cameroon). Thesis Doct., Univ. Kiel, 273p.

[20] Tamen J. (1994) - Contribution to the geological study of the Kapsiki plateau (Extreme-North, Cameroon): Volcanology, petrology and geochemistry. Thesis Doct. 3rd cycle Sc. Univ. Yaoundé, 132p.

[21] Boulangé B. (1984) - Laterite bauxite formations of Côte d'Ivoire. The facies, their transformations, their distribution and the evolution of the model. Thesis and Mém. ORSTOM. No. 175,341p.

[22]Hiéronymus B. Mineralogical study of bauxite deposits in West Cameroon. Cah Orstom (Sér Pédol),1, 1973, 97-110.

[23]COUSSOT P. Rheology of torrential lava. PhD thesis of the National Polytechnic Institute of Grenoble, 1992, 420p

[24]Trescases J.J. Supergene geochemical evolution of ultra-basic rocks in tropical zone. Formation of the nickel deposits of New Caledonia.ORSTOM, nº 78. ISBN : 2-7099-0362-8, 1975, 255p.

[25]Delvigne J. Pedogenesis in tropical zone. The formation of secondary minerals in ferrallitic media (thesis). Mém. O.R.S.T.O.M., no 13, Dunod, édit. Paris, 1965, 177 p.

[26]Lucas Y., Nahon D., and Eyrolle F. Genesis and functioning of soils in an equatorial environment. C.R. Acad. Sci., Paris, sér. IIA t. 322, sér. IIa., 1996, 1-16.

[27]Fopoussi Tuébué J. C. Contribution to the study of soils risen on trachyte on the southern slopes of the Bambouto Mountains (West Cameroon). Thes. Maitrise Fac. Sc., Univ. Dschang, 2001, 56p.

[28]Tsopjio Jiomeneck S.P., Tematio P., Wilson A., Yemefack M. Andosolization of soils on a strombolian cone at Mount Bambouto, Cameroon. Open J. Soil Sci., 1, 2011, 97-105.

[29]Duchaufour P. Pédologie : 1-pedogeneis and classification. Doc. 2nd ed. Masson, Paris, 1983, 491p.

[30]Bitom D., Azinwi Tamfuh P., Mamdem L., Zo'o Zame P., Leumbe Leumbe O., Banakeng L., Keugne R., Désiré Ndjigui P. Influence of Altitude on the Petrological Features of a Soil Climosequence in the Humid Tropical Zone of Cameroon. The Open Geology Journal. 7, 2013, 14-30

[31]Nascimento N.R., Bueno G.T., Fritsch E., Herbillon A.J., Allard Th., Melfi A.J., Astolfo R., Boucher H., Li Y. Podzolisation as a deferralitisation process. A study of an acrisol-podzol sequence derived from paleozoic sandstone in the northern upper amazonian basin. European Journal of Soil Science, 55, 2004, 523-538.

[32]Gassama N. Mechanism of the control of chemical elements in natural solutions. Habilitation to supervise researches. University Francois-Rabelais of Tours. Dept. Eart. Sci. 232p. Soil fertility treshold to diagnose deficiency in calcium, potassium and phosphorus in the sugar tree. Research note N°137, 2013, 18p

[33]Bocquier G, Muller JP, Boulangé B. Laterites: present knowledge and perspectives on their differentiation mechanisms. Paris: AFES, 1984.

[34]Tercinier G. Contribution to the knowledge of buaxitisation and allitisation phenomenons. Soils of South-west Pacific atoll karts. Cah. ORSTOM, ser. Pedol., vol. IX, n°3, 1971, 307-334.

[35]Edou-Minko A. Petrol ;ogy and geochemistry of laterites with stoneline of the Ovalaka gold lodging. Application to the prospection in humid equatorial zone. Thesis Doct., Fac. Sci., Geochim. Surface, Univ. Poitier. N° d'ordre 194, 1984, 183p.