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Methodology Article

A Geological Classification for the Rocks of Weathering

Waldo Lavaut Copa

Department of Geological Prospection, Institute of Geology and Paleontology, Havana, Cuba

Email address:
waldo@igp.minem.cu

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Abstract: The weathering constitutes a geological process of extraordinary importance, whose knowledge and utilization pertains to various spheres of the man's life, the animals and plants, as well it is used as substratum to several natural and applied technical sciences, such like geological engineering and constructions, mining and metallurgy, edaphology and pedology, climatology and geography, etc. The geological bodies that it generates: the mantles of weathering and soils, they are basis to life and offer end-rest: the cemeteries. Regardless of its diverse and ancient utilization, to the present does not exist an international agreement on the lexicon utilized for weathering, its taxonomy and nomenclature, which are the more diverse and prolific being an obstacle for computerization, the understanding and utilization of published and inedited literatures, as well as the relations of communication and working among specialists and other users of this science. Therefore, it becomes of urgency to achieve advances in the creation of an accepted worldwide lexicon of universal character for the weathering, and that it became part of the system of classification of rocks. With such motive, the author presents a lexicographical version for the rocks of weathering created in the base of the study and generalization of various classifications and lexicons more used in Cuba and in the rest of the world.

Keywords: Classifications, Rocks of Weathering, Mantles, Lexicon, Lithology

1. Introduction

Since in 1807 Buchanan in [1], at times of his trip from Madras (India) through several territories of the World, introduced the term "laterite" - remarking its reddish coloration and stratification lack - it bequeathed us an important and first-born definition that constitutes, without doubts, a contribution of relevance to the geologic knowledge of this formation. However, afterward and until the present its significance has been distorted, being applied this term indistinctly to different types of rocks and weathering mantles, and even, surprisingly, to denudation deposits and until to the purely sedimentary ones. Such a wrong use and problem have been motivated fundamentally by the lack of an international agreement for the classification of the rocks and deposits of weathering. This situation has already been resolved for other diverse types of rocks, where the consent has played an important role, existing, for example those hierarchical systems of classification adopted by IUGS in [2-4].

In the case of the weathering rocks, later on to Buchanan and in separate form, there have been created and applied several classifications of these types of rocks in the mark of different geologic schools and regions of the world. In the most of them has prevailed, and it has been reinforced with the advance of the time until our days, the lithological principle as a basis, since we are speaking about rocks. This way, in 1897 G. P. Merrill in [5] introduced the general term "regolith" (regolith, of the Greek ῥῆγος = "mantle" and λίθος = "rock") to name any friable (not consolidated) deposit having in situ genesis ("sedentary-residual") as well as transported ("transported regolith"), lying over the rocky hard surface of the Earth planet (although also nowadays is applied equally to the Moon, Mars, asteroids, etc.). The Merrill's classification meant an enormous advance step, since it constitutes an integral genetic scheme that included also the soil, like superficial part of the regolith, thing that he especially emphasized.

Previously to Merrill, in 1895 G. F. Becker in [6] introduced the term "saprolite" (from Greek σαπρος = putrid + λιθος = rock) to name the rocks of weathering that conserve the fabric

(texture & structure) of the original rock or “protolith”, while in the "pedolith" these attributes have already been destroyed. In 1975 J. J. Trescases in [7] introduces the term "saprock" to represent the rocks with light weathering (up to 20-30% alteration as a maximum, according to different authors). So that for an in situ regolith (sedentary-residual) the complete profile of weathering down the hole is represented by the sequence: pedolith - saprolith (i.e. saprolite+saprock) – protolith.

These classifications, characterized by a genetic-structural great sense, had a geologic meaning whose value has lasted until our days; and they have served as base for later more detailed classifications and with more lithologic and genetic reach. Nevertheless, no consent does exist worldwide on this topic neither a classification agreed, since its application is carried out in separated regions of the world and neither a combined collaboration has been propitiated to solve this problem.

2. Method

It is for this reason that for many years the author of this work has carried out actions directed to solve this internationally important problem, in [8-11]. However, until the current year and taking advantage of the favorable event of the VII Convention of Geological Sciences, held in Havana in April 2017, it was not possible to recapture this topic in a bigger magnitude and expose it to a great audience of geologists, including specialized workers on weathering and the laterite Ni-Co industry.

So the present contribution was made on the base of field observations, carried out throughout the islands of Cuba with the lithologic detailed study of 115 weathering profiles developed on diverse types of igneous, metamorphic and sedimentary rocks (basalt, andesite, ryolite, diabase, serpentinite, gabbro, gabrodiabase, granodiorite, diorites, monzodiorite, tonalite, sienite, plagiogranite, schists, shale, amphibolite, tuffs, sandstone, limestone, conglomerates), as well as data from drilling, pits and cuts of the weathering mantle of the supergenic Fe-Ni-Co Cuban deposits using the author's more than 35 years personal experiences acquired during his direction and participation in the geologic investigations and prospecting-exploration works in Cuba and Venezuela.

Additionally, the author carried out a bibliographical extensive search on the topic of the present work, supported in Internet, articles published in technical different magazines, doctoral related thesis, geologic and chemical-compositional data of weathering deposits from other parts of the world (Greece, Russia, New Caledonia, Indonesia, Philippines, Australia, Brazil, Venezuela, Borneo, Gabon, etc.), as well as coming from other Cuban authors. The range of time of the works consulted covers the last 120 years.

Figure 1. *Weathering profile on plagiogranite of Céspedez (Camagüey-Cuba). Photograph with the author (May, 2015).*

3. Results

3.1. The Process of Weathering

The weathering of the rocks on the terrestrial surface is a geologic natural process with particularities and grade of such complexity that it is impossible to include it in the nomenclature of other processes of formation of rocks, as erroneously make it some geologists, relating it with the sedimentary genesis and others that refer to the weathering like a genetic element of the cycle of the sedimentary rocks obviating the great diversity of rocks that this process generates. On the other hand, neither it can be related with the metamorphism, since it happens in an open system, although it does include the isovolumetric metasomatosis that operates fundamentally in the thickness of the different saprolites.

Therefore, the weathering is a natural supergenic phenomenon that leads to the mechanical disintegration and chemical decomposition of the rocks, accompanied by the accumulation, redistribution and selective evacuation of its chemical components, the formation of new minerals, the gradual loss of the fabric (texture & structure) of the protolith, and the collapse (shrinkage) of the more surface portion of the residual material. The weathering consists of several processes with gradual or superimposed action, depending of the geographical location and its parameters (climate, relief, tectonic, flora, fauna and others). These main processes involved are the following ones:

a) Physical processes: thermoclasty, gelifraction, hydroclasty, haloclasty.
b) Chemical processes: dissolution, hydratation, oxidation, hydrolisis, carbonatation.
c) Biological processes: decomposition by biologic agents.

For this reason weathering constitutes a geologic universal process, with its own characteristics and it is required to individualize it as such, independently of its incumbency in other constructive phenomena, as the formation of the soils

and sedimentary rocks, or destructive phenomena as the erosion that intervenes in the development of the relief. Consequently, the rocks whose genesis is directly the weathering deserve an individual place in the systematic of classification of the rocks.

It is important also the fact that, as a whole, the weathering process happens following different trends or evolution tendencies in function of the kind of protolith (mother or parental rock), accepting as constant the rest of the weathering factors (microclimate, topography, tectonic, etc.). This aspect can be well observed in the tendencies of the weathering of different rocks from the ophiolitic association in the region of Moa (Eastern Cuba), calculated by the author and plotted in the ternary diagram of figure 2. Also, in function of the local weathering factors (mainly the micro-relief and microclimate), for one type of protolith (example: harzburgite) similar weathering trains are developed, but not identical, i.e. some are not superimposed on other as has been proved.

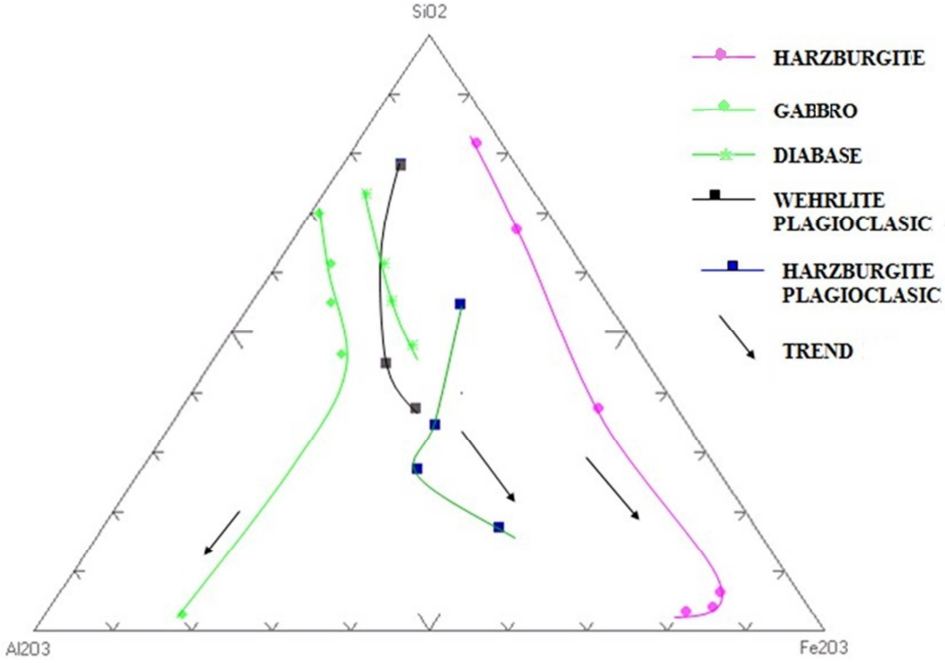

Figure 2. *Weathering trends of different ophiolitic rocks in Moa region (Eastern Cuba).*

3.2. State of the Art

The terminology that is applied to the moment for weathering and its rocks all over the world is diverse and complex. Noxious tendencies exist, as not defining well the weathering process, as was exposed above, and worse still not to see the difference between weathering and pedogenesis, as the last is a genetic process that goes beyond the weathering and that it has its particularities specified by the science of the soils.

The different approaches have led to the proliferation of terminologies corrupted with the use of different terms to represent the same thing and to mix Pedology terms and those of weathering indistinctly. One of the key terms of the weathering like it is "laterite" its use has been so distorted that some investigators have already ended up denying its application.

In summary, we can remark the global current problem of the lexicon of the weathering in the following aspects:

1. Application of regional and local multiple nomenclatures, including mixtures of terminologies of different origins, nature and significance.
2. Existence of corrupted terminologies and excesses of synonymies, for example: laterite = ferricrete, cuirrasse, plinthite, aluminic duricrete, pisolitic or nodular material, ferralitic soil, caolinitic lithomarge, bauxite, etc); limonite = ocher = red / yellow laterite.
3. Use of terminologies characteristic of other geologic processes, such as "horizon" which is a typical term of Stratigraphy and Pedology, instead of "zone" since the weathering mantles are zonal bodies (without stratification), conditioned by the key action of the metasomatosis and the lixiviation.
4. Incorrect use of terminologies, for example: sedimentary laterite; redeposited crust of weathering, which are bad used to designate deposits of denudation rocks or sedimentary rocks that well can be named applying the nomenclature approved for such rocks.
5. Not a system of classification of the rocks of the weathering was yet agreed internationally as there exists for other types of rocks.

4. Discussion

Proposal of Geological Classification for the Rocks of Weathering

Given the necessity to agree and to adopt an universal system of nomenclature of the rocks of the weathering, the author on the base of the analysis of a bibliographical extensive information on this geologic process and of the

more used different classifications in different regions of the world and in Cuba, has developed a nomenclature based on the grade of weathering of the parental material (protolith). Many of these terms are justified by their repeated use in time as long as more than one century of being introduced, for what is considered reasonable their current and future employment. Other terms, also canonical, had to be accompanied by epithets to facilitate and to specify their use, as well as some new terms have been introduced to better structure the nomenclature.

The proposed classification system consists of two levels: one general and other detailed, integrated by compact rocks and rocks with friability. The general level will use the term "Intemperites" to represent all the varieties of rocks that the process of weathering creates and a subdivision of the same ones in "Alterites" to represent the saprocks and saprolites, in correspondence with the metasomatic nature of these varieties, and for the neo-formation rocks that have lost the fabric of the protolith: a) "Lateritites" to designate laterites and bauxites and duricretes, and b) "Sialitites" to designate sialitic rocks in the upper part of the profile: loamose/arenose clayey rocks, clays and claycretes (illitic, halloysitic, montmorillonitic, minor caolinitic, etc.). The saprocks and duricretes are compact rocks, and the saprolites and laterites and bauxites and sialitites are friable rocks.

The classification scheme looks as follows:

1. ALTERITES (Saprock and Saprolites)
2. LATERITITES (Laterites, bauxites, duricretes)
3. SIALITITES (Clays and clayed rocks)

The second level (detailed) of this nomenclature is based on the grade of weathering of the parent material (protolith). This is the basis of several classifications broadly used for the aims of the construction and other applications, in [12, 13]. As it is known, the grade of weathering of the rocks is conditioned by the stability to the weathering process of the minerals that compose the protoliths (Goldlich's serie in [14]) in front of the levels of humidity and temperature, i.e. the climate/microclimate, also in [15-19]. The detailed classification is shown in the ternary diagram exposed in the following figures 3 and table 1.

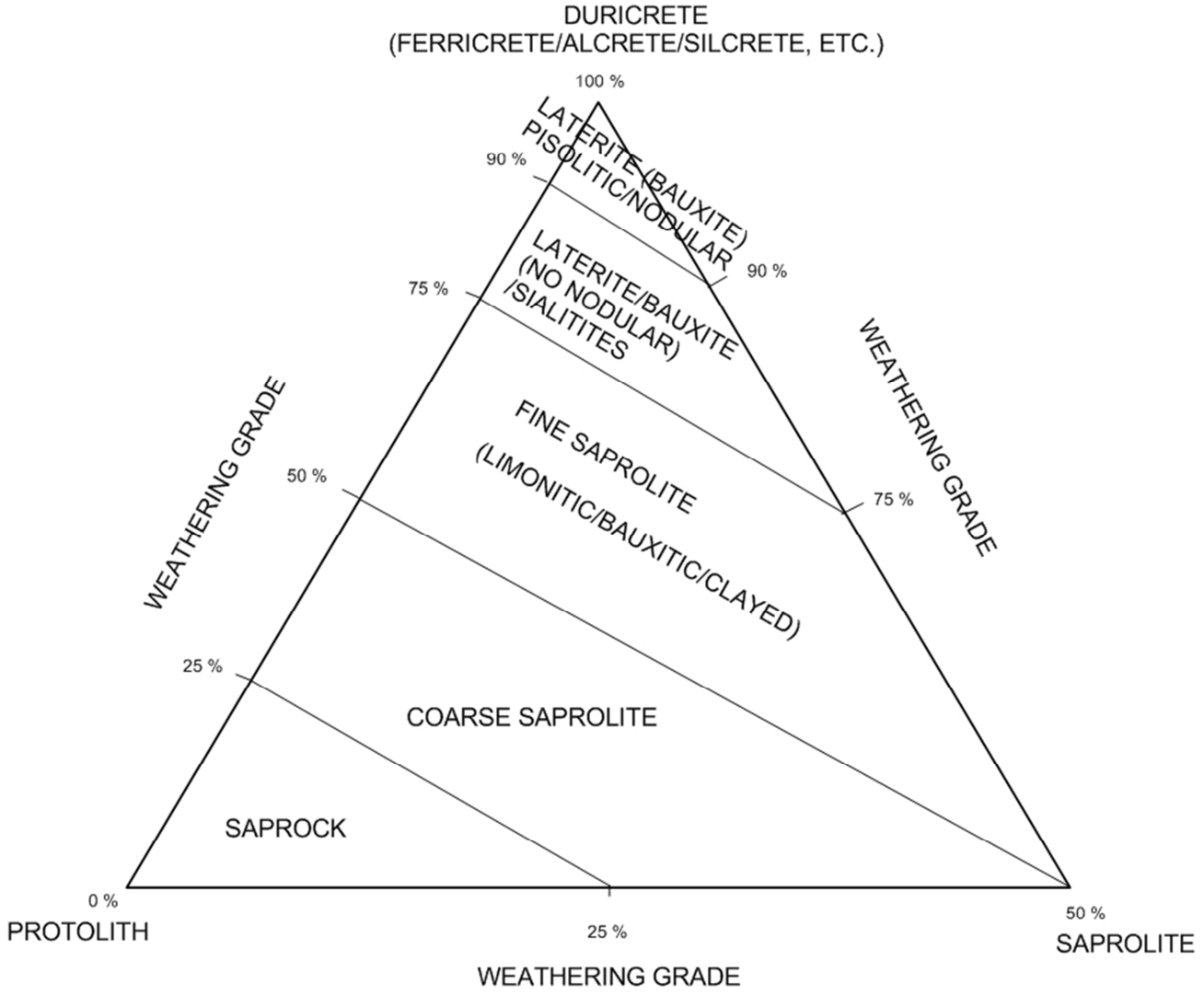

Figure 3. *Second level (detailed) of the classification for the rocks of weathering ("intemperites") as a function of the degree of the weathering of the parent rock (protolith).*

Table 1. *Scale for determining the grade of weathering of rocks.*

Class of Weathering	Grade (scale)	Type of intemperite	Lithological characteristics	Consistency of the material	Grade after anon, 1977; dearman, 1986
Completely weathered (100%)	VII	Duricretes	Massive/ nodular/pisolitic material (friable/cemented)	No crumbable with hands and fingers	-
Extreme weathered (90-100%)	VI	Laterite\Bauxite\ Sialitite	Totally degraded material with destroyed fabric of the protolith	Crumbable with hands and fingers	VI
Highly weathered (75-90%)	V	Fine Saprolite (Limonitic, Bauxitic, etc.)/Claycrete	Totally degraded material with yet discernible fabric of the protolith	Readily slakes in water, pick easily indents surface	V
Very weathered (50-75%)	IV	Fine Saprolite Clayey (Montmorillonitic, Nontronitic, Caolinitic); Serpentinitic, etc.)	Degraded material more than the half with the fabric of the protolith conserved	Plastic, not readily slakes in water and may be broken with hands	IV
Partially weathered (25-50%)	III	Coarse Saprolite (Rocky or arenose)	Degraded material less than the half with the fabric of the protolith conserved containing altered fragments and even blocks	Semi-plastic or no plastic, hammer blow makes drumming sounds and the altered fragments/blocks conserve hard nucleus	III
Lightly weathered 10-25%	II	Saprock (Blocks or in situ)	Discontinue discoulorated weathered surfaces with some degraded material on them	Hammer blows sound dull and need several blows to break	II; IB
Fresh	I	Protolith	No evidence of weathering	Shows the intrinsic characteristics of the type rock	IA

The denomination of a weathering rock in particular applying the outline of the figure 3 is the name of the intemperite with an epithet referred to the petrographic variety of the protolith. Examples: granitic coarse sarprolite, gabro bauxite, harzburgitic pisolitic laterite, etc.

For the duricretes do exists a nomenclature that up to now have been used correctly which is based on the chemical/mineral composition and the compactness of the varieties that can be adopted worldwide, excepting for the broad local synonymies. The duricretes for this classification are the following: "Silcrete" for the oxides of siliceous compositions (amorphous silica, residual quartz, etc.); "Ferricrete": composed by iron oxi-hidroxides (essentially goethite, hematite, minor magnetite); "Alcrete": for aluminic composition (gibbsite, boehmite); "Calcrete": for calcium carbonate ($CaCO_3$); "Gypcrete": for gypsic segregations ($CaSO_4.H_2O$); "Magnesicrete": for the magnesite, usually botryoidal ($MgCO_3$); "Salcrete": halite or salt gem (NaCL). The duricretes generally are not completely pure since they carry particles, mostly of the concomitant minerals, and they even can be partially silicified. Their genesis is enough explained in publications and geologic dictionaries.

In this way the proposed classification for the rocks of weathering allows to solve the wrong use of the old term laterite that here it will represent only the ferruginous types, i.e. the ferruginous lateritites where the iron sesquioxides prevail over the aluminous sesquioxides; and also bauxite will correspond only to the aluminous lateritites where the aluminum sesquioxides prevail over the iron sesquioxides. This solves a lexicographical great problem that has lasted many years in the application of both terms eliminating the negative sequels of that bad use.

Other general aspects of the present classification are referred to the proposal of elimination of certain essentially incorrect terminologies. The concrete proposals in this respect are the following ones:

a) The use regolite instead of mantle or crust, as these last two terms represent the internal structure of the planet. This way, we would have: eluvial regolite for the residual ("in situ") case; deluvial / proluvial / coluvial / eolical regolite for denudation deposits composed of removed by rain, gravity or wind weathering products.
b) Exclude the alluvial, marshy and marines deposits of the nomenclature of the rocks of weathering, as they are sedimentary rocks and have a distinct genesis.
c) Eliminate the synonymies that proliferate in the denomination and classification of the rocks of the weathering such as regionalisms and terms with a different root as those proposed here, for example: plinthite, cuirrasse, taquilita, canga, lithomarge, ocher, etc.
d) Eliminate from the lexicon of the weathering the pedological terminology, such as soil, horizon, ferralite, oxisoil, etc., that is used indiscriminately to represent aspects characteristic of the weathering what leads to the terminological mixture and the confusion.

5. Conclusions

1. Not a system of classification for the rocks of weathering agreed internationally exists as there is for other types of rocks.
2. The application of regional and local multiple nomenclatures, including mixtures of terminologies, constitute a main problem to solve in front of the theoretical, practical and computer necessities.
3. The system of nomenclature for the rocks of weathering presented in this proposal is a good classification system whose terminology enjoys universality for what constitutes an effective base for the solution of this

problem.

4. The present contribution solves the lexicographical current problem for the classification of the rocks of weathering and it is recommended to international competent organizations (IUGS, UNESCO IGCP, etc.) for their approval and general application.

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