TYPOLOGICAL SOILS MAPPING

METHODOLOGY

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With the acquired experience in african cartography we were able to elaborate an original method capable of transmitting a maximum of information through the legends of morphological and edaphic restraint maps. This information concerns soils, landscapes and their physico-chemical and morphological characteristics. The results are expressed either by numbers or with a "typological language" based on the notion of "diagnostic horizon"

Using this language brings about an important change to expression and description of soils. It enables us to identify, name and characterize the different pedological horizons. Thus transcribed information is both qualitative and quantitative. Map - and legend - users must exert themselves to remember typological words and their meaning in order to completely profit from the information. It will be a restricted effort owing to the relationship between this language and the usual keys of the french CPCS classification, but a justified one which gives a better utilization of pedological field data and an analytical one.

This short paper defines the different words of the typological language and mentions its combinative possibilities and its capacities to describe and quantify. It shows the methodological steps (notion of pedon, pedological segment, and landscape, mosaic of soils ..) and explains the legends so as to use them.

TYPOLOGICAL LANGUAGE - DEFINITIONS

Each word of the language includes its definition and etymology as well as the derived prefix and adjectives. These definitions result from several publications (1). All the words make up a language which allows to study several levels of diagnosis and exactly define a comprehensive structural scheme of soils.

Major diagnosis (or : first diagnostic level)

HUMITE (derived from humus)

Designates a pedological material characterized by the presence of organic matter, not disclosed except by colour and associated with mineral substance.
It is distinguished by its generally homogeneous colour (brown, maroon, more or less dark grey ...).
In the Munsell code, values are distributed between 2 and 5, chromas between 0 and 3 in 10 R - 2,5 YR - 5 YR - 7,5 YR - 10 YR hues and also 2,5 Y and 5 Y.
Other characteristics : texture (special feel owing to organic matter), organization (structure, rooting ...)

Prefix : humo Adjective : humic

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(1) BEAUDOU (A.G.), BLIC (Ph. de), 1978 - Etude typologique du complexe sol-plante en cultures intensives semi-mécanisées dans le centre ivoirien - Cah. ORSTOM, sér. Pédol., XVI, 4, 375-396.

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CHATELIN (Y.), 1979 - Une épistémologie des sciences du sol - Mém. ORSTOM n° 88, 151 p. Paris.

CHATELIN (Y.), BOULVERT (Y.), BEAUDOU (A.G.), 1972 - Typologie sommaire des principaux sols ferrallitiques et ferrugineux tropicaux étudiés en République Centrafricaine - Cah. ORSTOM, sér. Pédol., X, 1, 59-75.

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RICHARD (J.F.), KAHN (F.), CHATELIN (Y.), 1977 - Vocabulaire pour l'étude du milieu naturel (Tropiques humides) - Cah. ORSTOM, Sér. Pédol., XV, 1 43-62.

Melanumite (from greek melanos : black, and from humus).

A major variant of humite. Humiferous pedological material with high or very high organic matter content, often an intergrade toward necrumite. Colouration is homogeneous : black, sometimes very dark grey, more or less a greenish or bluish shade : value 2 to 3, chroma 0 to 2 in 2,5 Y and 5 Y hues. In 10 YR and 7,5 YR hues, respectively colours 2/1 and 2/0. Generally described in flats and alluvial plains. Often an unbroken or coarse fragmental structure.

Prefix : melanumo Adjective : melanumic

Coprumite (from greek copros : excreta, and from humus).

A major variant of humite which designates a more or less slack assemblage of organomineral aggregates and microaggregates, transient by nature, showing a high activity of fauna. Never corresponds to biological edifices.

Prefix : coprumo Adjective : coprumic

Arumite (from latin arare : to cultivate, and from humus)

A major variant of humite (or of melanumite) transformed by cultural technics and practices, responsible for specific and various pedological organizations and features, with generally temporary characteristics (result of ploughing, structure ...).

Prefix : arumo Adjective : arumic

NECRUMITE (from greek necros : corpse, and from humus).

Designates dead and decomposed vegetal matter (distinguishing it from necrophytion). Differenciated from humite because vegetal matter is still visually recognizable.

Prefix : necru Adjective : necrumic

NECROPHYTION (from greek necros : corpse, and from phuton : plant).

Designates undecomposed dead vegetal matter : leaves, branches, truncks, fruits, seeds.. cut, laid, fallen down on the soil.

Prefix : necro Adejctive : necrophytic

HUMOSTRUCTICHRON and STRUCTUHUMITE

Intergrade horizons between humite and structichron. They immediately come after humite and are distinguished by an organic impregnation which gives them a dull colouration. Value 3 to 5, chroma 3 to 5. Humostructichron is nearer to structichron, structihumite nearer to humite. These horizons are homogeneous when colouration is regular, or heterogeneous when organic matter is distributed in patches, tongues, etc ...

Prefix : humostructi Adejctive : humostructichromic
structihumo structihumic

STRUCTICHRON (derived from structure and from greek chroma : colour)

Loose mineral pedological material with various, homogeneous, bright and pure colours (yellow, red, violaceous, brown, ochre, beige...). Value 4 to 6, chroma 5 to 8. Texture is variable. There is no recognizable metallic oxides and/or hydroxides individualization. The structural organization is really pedological without any ressemblance to the parent material. Contains at least 10 percent of mineralogical clays.

Prefix : structi Adjective : structichromic

REDUCTON (from reduced)

Loose pedological material, characterized by the following colours : grey, bluish grey, greenish-grey, white, beige or very light yellowish. Value 4 to 8, chroma 0 to 2 in 10 YR, 2,5 Y, 5 Y hues and in the whole gley hue. Texture is essentially clayey or silty clay. Structure is amerode or

very coarsely anguclode. Often associated with oxidon, generally in juxtaposition.

Prefix : reducto Adejctive : reductic.

OXIDON [1] (from oxide)

Loose pedological material with bright, homogeneous colours, generally yellow or red, sometimes very dark red to black. Value 3 ro 5, chroma 5 to 8 in 10 R and 2,5 YR hues. Value 4 to 6, chroma 6 to 8 in 5 YR and 7,5 YR hues. Weak or very weak mineralogical clay content (below or equal to 10 percent). Fine or very fine texture. Not plastic in wet conditions. Structure generally amerode. Contains very high amounts of metallic oxides and hydroxides (Iron, aluminium, manganese, nickel, chrome, cobalt...) either all mixed, or with one of them predominent. Often associated with reducton, generally in juxtaposition.

Prefix : oxido Adjective : oxidic .

RETICHRON (from latin reticulum : net, and greek chroma : colour)

Most often loose pedological material with patches or mottlings drawing a red or red ocher coloured net on a yellow ocher, yellow or beige ground. The opposite can occur : yellow, yellow ocher or beige patches or mottlings on a red or red ocher ground. Patches and mottlings generally make up an alveolar or reticular pattern in which the mesh measures several centimenters. It is an evolved mineral set with mineral composition and organization having no macroscopic analogies with the parent-rock.

Prefix : reti Adejctive : retichromic

Duriretichron (from french dur : hard)

A variant of retichron characterized by a generally slight hardening of the coloured patches (or mottles).

Prefix : durireti Adjective : duriretichromic

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(1) FAUCK (R.), LAMOUROUX (M.), PERRAUD (A.), QUANTIN (P.), ROEDERED (P.), VIELLEFON (J.), SEGALEN (P.), 1979 - Projet de classification des sols - ORSTOM - 301 p., Paris.

VERTICHRON (from vertisol and from greek chroma : colour)

Loose pedological material with homogeneous colours : brown, olive green. Value 4 to 6, chroma 2 to 6 in 2,5 Y and 5 Y hues. Texture is clayey or very clayey with 2/1 clays. The various sized fragmental wedge structure is sphenoclode. This material is characterized by the presence of striated and/or shiny, warped surfaces, sometimes very large-sized (slickensides). Individualizations of carbonates (Ca, Mg), sulfates (Ca, ...) and metallic oxides and hydroxides (Mn, Fe, ...) are frequent.

Prefix : verti Adjective : vertichromic

ALTERITE (from alteration)

Loose and cohesive material resulting from a first weathering of often heterogeneous coloured and textured rocks. Even when it is completely loose, the alterite never acquires a pedological organization (particularly it never appears as aggregates).

Prefix : alte Adjective : alteritic

Alloterite (from greek allos : other)

A major variant of alterite where the main features of parent-rock structure and organization have completely disappeared.

Prefix : allote Adjective : alloteritic

Isalterite (from greek isos : same)

A major variant of alterite where parent-rock structure and organization are obviously preserved.

Prefix : isalte Adjective : isalteritic

STERITE (from greek stereos : hard)

Hardened, continuous pedological material, characterized by a concentration one or several soil elements. Sterites are rarely homogeneous and offer a very wide variety of colours and facies. Their mineralogical nature

is also diversified (sesquioxidic, calcareous, magnesian ...)

Prefix : steri Adjective : steritic

Fragisterite (from latin fragilis : fragile)

A major variant of sterite with low hardness. Fragments of fragisterite can be broken more or less easily by hand.

Prefix : Fragisteri Adjective : fragisteritic

Petrosterite (from greek petro : stone)

A major variant of sterite with a high hardness. It can be broken only with a tool.

Prefix : petrosteri Adjective : petrosteritic

LEUCITON (from greek leucos : white)

Pedological material, white, grey or very light beige coloured. Value 7 to 8, chroma 1 to 3 in 5 YR and 10 YR hues. Value 8 and chroma 0 to 2 in 7,5 YR hue. Mainly made up of quartzeous, various-sized elements (arenic, rudic), sometimes graded. Intergranular porosity is very high. The boundary with other materials is always very clear. This material essentially occurs in podzols, solodized solonetz, planosols, leached soils, ...

Prefix : leuci Adjective : leucitic

Durileuciton (from french dur : hard)

A major variant of leuciton whose elements are bound together with a generally argillosiliceous cement.

Prefix : durileuci Adjective : durileucitic

LAPIDON (from greek lapis : rock)

Discontinuous material, characterized by a concentration of coarse elements more than 2 mm diameter and of various types and mineralogical natures (lithorelics, pseudomorphosed minerals, loderelicts, nodules, concretions, or sesquioxidic, calcareous, magnesian sterites blocks...). Its origin

is most often not directly recognizable (allochton or autochton). Generally associated with another loose diagnosis such as structichron, humite, retichron, vertichron, alterite ...

Among the most frequently observed types of lapidon, we can mention :

- gravolic lapidon : composed of nodules and/or concretions and/or sesquioxidic sterites blocks (Fe, Mn...)
- gravelly lapidon : composed of quartzeous elements very often derived from lodes
- rocky lapidon : composed of unweathered rock elements (lithorelicts)
- alteritic lapidon : composed of weathered rock elements (altelithorelicts)
- carbonated lapidon : composed of nodules; concretions and/or carbonates blocks (Ca, Mg ...).

Prefix : lapido Adjective : lapidic

Epilapidon (from greek epi : over)

A major variant of lapidon overlying the soil surface. Elements can be less than 2 mm diameter. They occur in arenite and rudite size grades.

Prefix : epilapido Adjective : epilapidic

ENTAFERON (from greek entha : here and there, and from pherô : to transport)

Drift material morphologically recognizable, often heterogeneous, with a variable granulometry : lutic (clays and loams) and/or arenic (sands) and/or rudic (gravels, stones, blocks, pebbles ...). Without pedological organization or with a weakly defined one, which never conceals the drift organization. Sometimes stratified and/or graded-bedded. Its origin can be variable (alluvial, colluvial, marine, eolian, volcanic, glacial ...)

Prefix : enta Adjective : entaferic

Epientaferon (from greek epi : over)

A major variant of entaferon overlying the soil surface

Prefix : epienta Adejctive : epientaferic

REGOLITE (from reg)

Designates very large-sized rocky blocks and unweathered parent rock, geologically in situ.

There are numerous variants according to the petrographical and geochemical nature of the rock.

Prefix : rego Adjective : regolic

DERMILITE (from greek derma : shin, and lithos : stone)

Designates the structure resulting from a reorganization of soil surface by the beating effect of rain (argillous and/or loamy crust). Morphologically characterized by a packed, oriented, stratified aspect owing to the deposit of fine particles. The under limit is generally underlined with a vesicle train. Size of dermilite constituting elements is less than 1 mm (lutic, micro-arenic). According to the complexity of organization, dermilites are subdivided into simple, coumpound and polyphased dermilites.

Prefix : dermo Adjective : dermilic

SEMETON (from greek semeîos : feature)

Set of pedological features (except cutans, nodules, carbonated and sesquioxidic concretions) with various shapes and natures : effluorescences, dendrites, crystallaria (gypsum), pedotubules, biomicro-aggregates ...

Prefix : seme Adjective : semetic

CUTANON (1) (from cutan)

Pedological feature corresponding to a modification of texture and/or structure and/or fabric at natural surface in soil materials (surfaces of aggregates, skeleton grains, lapidon walls of voids).
This feature is characterized by the concentration of particular soil constituent or in situ modification of the plasma. Cutans can be composed of any of the soil elements or any of the component substance of the soil material.

(1) BREWER (R.), 1976 - Fabric and mineral analysis of soils Robert E. Krieger Publishing Company - Huntington, New Work.

Among the most frequently observed cutans, we can mention :

- argilans : composed of clay
- ferrans : composed of iron oxides and hydroxides
- organans : composed of organic products.

There are numerous variants resulting from mixing different elements : ferriargilans, argiloferrans, organo argilans, organoferrans ...

Prefix : cutano Adjective : cutanic

ZOOLITE (from greek zoon : animal, and lithos : stone)

All the constructions owing the zoological activity (ant-hills, termitaries, turricules ...)

Prefix : zoo Adjective : zoolitic

TEPHRALITE (from greek tephra : ash and lithos : stone)

Vegetal ashes and coals

Prefix : tephra Adjective : tephralite

RHIZAGE (from greek ridza : root and agogos : which conduces)

A vegetal set of roots principally composed of more or less lignified conductive elements.

Prefix : rhiza Adjective : rhizageous

RHIZOPHYSE (from greek ridza : root, and phusis : expansion)

Vegetal set constitued with a fine assimilating root system (root-hairs ...)

Prefix : rhizo Adjective : rhizophytic

HYDROPHYSE (from greek hudros : water and phusis : expansion)

Physical component : free run-off water or infiltration water (saturation level - water table).

Size grades (1)

They principally concern the following diagnosis :

- Lapidon
- Entaferon
- Leuciton
- Dermilite

LUTITES (0-50 µ)

- Microlutites (0-20 µ)
- Macrolutites (20-50 µ)

ARENITES (50 µ - 2 mm)

- Microarenites (50 µ - 1 mm)
- Macroarenites (1 mm - 2 mm)

RUDITES (> 2 mm)

- Microrudites (2 mm - 2 cm)
- Mesorudites (2 cm - 7,5 cm)
- Macrorudites (7,5 cm - 20 cm)
- Megarudites (> 20 cm)

Secondary diagnosis (or : second disgnostic level)

They are useful for describing soil structure. As for major diagnosis, all the substantives are constructed with a greek or latin prefix and a suffix : - ode or - clode, derived from english clod.

ALIATODE (from greek aleiat :flour)

Corresponds to "powdery" or "floury", "degraded" structures, characterized by very small elements (microaggregates) and a continuous arrangment without cracks or large structural surfaces. Very porous and crumbly under the pressure but it stands up very well to erosion. (Elementary descriptive schemes are poorly adapted to accomodate these structures).

Prefix : aliato Adjective : aliatodic

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(1) Chambre syndicale de la recherche et de la production du pétrole et du gaz naturel, 1974 - Méthodes modernes de géologie de terrain - T. 1. Principes d'analyses sédimentologiques. Ed. Technip. 97 p. ISBN 2-7108 - 0255-4.

PSAMMOCLODE (from greek psammos : sand)

An arenic material structure with less than 15 to 20 percent of clay. Sands are sometimes more or less coated and joined together with clay.

Prefix : psammo Adjective : psammoclodic

GRUMOCLODE (from latin grumus : hillock)

Aggregates with curve, mammilated, wrapping shaped structural faces : the characteristic element is a rounded aggregate. This structure is essentially described in humites rich in organic matter and surrounding root-hairs. Its average size is about one centimeter.

Prefix : grumo Adjective : grumoclodic

NUCICLODE (from latin nucis : nut)

Aggregates with more or less curve and mammilated faces and rarely well expressed blunt edges, resulting from some splitting or other of a loose material with a more or less massive structure. Well defined rounded or ovoid aggregates are rare.

Prefix : nuci Adjective : nuciclodic

ANGUCLODE (from latin angulus : angle)

The planes of the separation faces and sharp edges constitutes a structure of well defined angular aggregates

Prefix : angu Adjective : anguclodic

Aroclode (from latin arare : to cultivate)

A major variant of the anguclode structure owing to soil works which isolate numerous, often large-sized clods, characterized by smoothed faces

Prefix : aro Adjective : aroclodic

Cuboclode (from cube)

A major variant of the anguclode structure characterized by various sized and well delimited aggregates, with generally plane faces materializing geometric volume such as cubes, parallelepipeds...

Prefix : cubo Adjective : cubocludic.

Lepiclode (from creek lepis : scale, flake)

A major variant of the anguclode structure characterized by various-sized thin lamellar aggregates with nearly parallel plane faces.

Prefix : lepi Adjective : lepiclodic

Prismoclode (from prism)

A major variant of the anguclode structure characterized by generally large-sized prismatic aggregates with a vertical dominant trend and more or less plane faces.

Prefix : prismo Adjective : prismoclodic

Styloclode (from greek : stélé : column)

A major variant of the anguclode structure of which aggregates are medium or coarse-sized prisms with more or less rounded summits. Essentially met in solodized solonetz and some planosols ... (columns, colonnettes ...).

Prefix : stylo Adjective : styloclodic

ECLUTODE (from greek eclutis : free)

Grumous or angular aggregates of which the size is rarely measuring more than 20 mm, practically separated from each other or possible bound together with fine roots.

Prefix : eclu Adjective : eclutodic

SPHENOCLODE (from greek sphen : corner)

A structure characterized by various-sized aggregates, well-delimited with plane or lightly convex faces, corner-shaped. Generally met in verti-chrome argillous horizons. Faces can be shiny (lucic, prefix : luci-) or striated (prefix : strio-) or strio-lucic, or luci-striated ...

Prefix : spheno Adjective : sphenoclodic

PAUCICLODE (from latin paucus : scarce)

Massive and discontinuous structure with plane, irregular structural faces and angular edges resulting from a slight splitting and which practi-cally never separate out into really well formed angular blocky aggregates.

It is rather a jointing into various-sized and shaped polyhedrons. Natural faces and artefacts derived from breakage yield angular blocks of variable size.

Prefix : pauci Adjective : pauciclodic

AMERODE (from greek ameros : individed)

Massive and continuous structure, sometimes with rare cracks, fine loose mineral or organomineral materials, without prominent organization.

Prefix : amero Adjective : amerodic

Complementary diagnosis

It is useful for gathering many pedological traditional informations such as colour, texture or chemical, physical, biochemical or mineralogical characteristics.
Diagnosis and terminologies have been used for a long time and are used here without any modification. In some respects these caracteristics can appear as the most significant. Their position as complementary characteristics in the order of description does not mean that they must have a minimized part.

Combined diagnosis

It applies to horizon regroupings, such as humite and structichron, or lapidon, sterite and alterite ... They are multiple possibilities but two great entities can be separated :

- the upper part of soil, seat of biological and rooting activity : the APEXOL;
- the lower part of soil which directly follows the apexol : the INFRASOL.

APEXOL (from latin apex : summit)

The following horizons can be present in the apexol :

Humite	Necrumite	Humostructichron	Structichron
Melanumite	Necrophytion	Structihumite	Oxidon
Coprumite			Vertichron
Arumite			

arenic Lapidon
arenic Leuciton
lutic and/or arenic Entaferon

Some horizons such as structichron, oxidon, vertichron, lutic and arenic entaferon, lapidon and arenic leuciton can be well developed. In such conditions, only the upper part of these horizons, which is directly related to biological activity and fertility, belongs to apexol. The under limit of apexol is then conventionnally determined. In New Caledonia, the maximum depth of apexols attains 120 cm, but that can vary from one region to another according to soils development.

Apexols can be classified in terms of thickness, as :

Lepto-apexols (from greek leptos : thin)

They are comprised only of a humite and/or their variants (melanumite, coprumite, arumite) and/or a necrumite, necrophytion and sometimes a structihumite.
These horizons directly overlay one of the infrasol ("restraint horizon")

Brachy-apexols (from greek brachus : short)

Deeper than lepto-apexols, they are composed of the same horizons to which may be added different horizons of the apexol. Two types of brachy-apexols are admitted, according to the degree of development and to the constituting horizons :

- humic brachy-apexols (type 1)

The horizons of lepto-apexols are here completed with a humo-structichron, a humovertichron or a humoentaferon... or any other apexol horizon with humic characteristics.
The soil thickness is under 80 cm. The Infrasol begins with a "restraint horizon".

- strict brachy-apexols (type 2)

They are composed of the same horizons as the humic brachy-apexols with, the other apexol horizons as well (structichron, oxidon, vertichron, lapidon, leuciton, entaferon).

The soil thickness is always under 120 cm. In this case, the infrasol begins also with a "restraint horizon".

Ortho-apexols (from greek orthos : straight)

They have the same composition as the strict brachy-apexols and are only distinguished by their thickness, at least 120 cm.

The infrasol always begins either with a structichron, or a vertichron, an oxidon, an entaferon (lutic and arenic) an arenic lapidon or even an arenic leuciton.

INFRASOL (from latin infra : under)

The following horizons can be observed :

- Structichron
- Oxidon
- Vertichron
- lutic and/or arenic Entaferon
- arenic Lapidon
- arenic Leuciton

These six horizons, which are classically present in apexol, do not represent restraint levels. They can be observed in infrasol only when apexol is well defined (ortho-apexol) or when they follow a "restraint" horizon usually present in infrasol, such as :

- Reducton
- Retichron
- Duriretichron
- Alterite
- Sterite (duri - and fragisterite)
- rudic Leuciton
- Durileuciton (rudic and/or arenic)
- rudic Lapidon
- rudic Entaferon
- Hydrophyse
- Regolite

Infrasol represents the soil part which is not directly connected with biological activity and fertility.

TYPOLOGICAL LANGUAGE AND QUANTIFICATION

Typological language was constructed not only for discribing but also for expressing numerical values. Then it constitutes a combinative which terms can be connected in many ways. With some elementary examples, we shall define the used writing rules (1).

(1) BEAUDOU (A.G.), 1978 - Note sur la quantification et le langage typologique Cah. ORSTOM, ser. Pedol. XV, 1, 35-41.

Juxtapositions

Some quantitative classes, easily recognizable in the field have been chosen in the case of juxtaposed diagnosis, which exactly fill delimited volumes.

0 - 1 %
1 - 5 %
5 -15 %
15 -30 %
30 -45 %
45 -55 %

In the case of two juxtaposed diagnosis, such as structichron and lapidon, we can write when structichron diagnosis prevails :

0 %	of Lapidon :	STRUCTICHRON
0 - 1 %	of Lapidon :	STRUCTICHRON psile(1) lapidic
1 - 5 %	of Lapidon :	STRUCTICHRON stigma(2) lapidic
5 -15 %	of Lapidon :	STRUCTICHRON phasis lapidic
15 -30 %	of Lapidon :	STRUCTICHRON lapidic
30 -45 %	of Lapidon :	Lapido-STRUCTICHRON
45 -55 %	of Lapidon :	STRUCTICHRON-LAPIDON ou LAPIDON-STRUCTICHRON

Over 45-55 % of Lapidon, structichron diagnosis ceases to prevail, then we write :

55-70 %	of Lapidon :	Structi-LAPIDON
70-85 %	of Lapidon :	structichromic LAPIDON
85-95 %	of Lapidon :	LAPIDON phasis structichromic
95-99 %	of Lapidon :	LAPIDON stigma structichromic
99-100%	of Lapidon :	LAPIDON psile structichromic
100 %	of Lapidon :	LAPIDON

So, we can regularly and simply quantify a juxtaposition of two materials which is extremely frequent in soils. In the same way, we can describe and quantify juxtapositions of 3, 4 diagnosis or more. In these complex cases, diagnosis have to be gathered, either through their nature (fines on the one hand, coarse elements on the other hand) or through localization... in order to have only two elements to quantify. Then in each so-constituted group, elements are quantified, each related to the others.

We can then write :

- STRUCTICHRON lapidic, phasis semetic
- Alté-LAPIDON structichromic, stigma semetic

(1) - psile : from greek psilos : alone
(2) - stigma : from greek stigma : sting, spatch.

Thus it is possible to simply and concisely express some juxtapositions sometimes qualitatively and quantitatively very complex.

Intergrades

It is sometimes difficult to clearly distinguish in soils the volume filled with two or several diagnosis. They have extremely gradual limits and a certain continuity appears between the different materials. They are intergrades. This being so, quantification is difficult and we keep only two possibilities for writing. Then we show the presence of a complex diagnosis with its prevailing pole. For example, we can write for an alterite and structichron intergrade, either :

- altestructichron (prevailing pole : structichron)

or :

- structialterite (prevailing pole : alterite)

The same proceeding can be applied in more complex cases with three diagnosis or more :

- altereductostructichron (prevailing pole : structichron, then going in decreasing importance : reducton and alterite).

CARTOGRAPHY : NOTION OF VOLUME AND OF SOIL-CONTENTS

THE PROBLEM OF BOUNDARIES

Each pedological map proposes a certain cutting-up of space. So produced units have to be defined with their soil contents. We are going to successively examine these different notions :

VOLUMES

This section observation reveals the presence of different organizations. In the same way, a horizon shows several distinct units, a sequence shows several different profiles spaced out all along one side... etc. So, a range of privileged orders of size is revealed by actual means of analysis. These orders of size represent pedological volumes. It is then possible to distinguish, in descending order :

Order n + 3 : pedological region
Order n + 2 : pedological landscape
Order n + 1 : pedological segment
Order n : pedon
Order n - 1 : horizon
Order n - 2 : phasis
Order n - 3 : microscopic fabric

This notion of volumes approximates those of geographs(1)

1)- The three-dimensional profile or pedon

We shall assimilate the three-dimensional pedological profile with the pedon. BOULAINE (2) defines it as the required and sufficient volume for characterizing a soil. This order of size for pedological volumes is specially adapted to large scale cartography (1/50.000 and more).

We shall immediately name them with the typological terminology by identifying apexols and infrasols simultaneously.

The detailed pedological contents will be given by the enumeration, in terms of typological language, of inferior orders constituting volumes of pedons, horizons and also phasis.

2)- The pedological segment

In New Caledonia, toposequences are not monotonous. When going over toposequence, we can always recognize several segments. Each of them is marked with a variation which seems well-ordered. The pedological segment is then characterized by a certain type of evolution and an interfluve top segment will be different from the one of a side, itself different from the one of a valley ...

Characteristics of proximate designation are essentially pedologic. They refer to the main morphological features of soils or, in other words, to the

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(1) - TRICART (J.), 1965 - Principes et méthodes de la géomorphologie Masson, 496 p.
- BERTRAND (G.), 1968 - Paysage et géographie physique globale - Esquisse méthodologique - Rev. Geogr. Phys. et Sud-Ouest XXXIX, 3, pp. 249-272.

(2) - BOULAINE (J.), 1969 - Sol - Pédon, Génon. Concepts et définitions. Bull. Ass. Fr. Etude du Sol - 2. pp. 31-40.
- BOULAINE (J.), 1975 - Géographie des sols - PUF. Coll. Le géographe n° 17 - 199 p.

main pedogenesis processes. Genetic terms can be used when granting that connections occur between processes (hardpan, hydromorphy .....) and morphologic features (sterite, retichron, oxido-reducton, etc...). The position of the segment is then precised in the relief : interfluve top, upper part of a side, connecting zone, etc... Means used to express the soil contents are those of typological terminology.

3)- The pedological landscape

It is also called "morpho-pedological landscape" (1) . This second term underlines the importance of morpho-pedological characteristics for identifying this envelope. The geological landscape is generally useful for showing volumes composed of toposequences. A toposequence is a soil section stretching from upper points of relief to lower ones. Numerous studies have been made on this volume, both in Central - and West Afrika (BOCQUIER, 1973; BOULET, 1978). It is easy for us to imagine that two separate toposequences should be similar it they fill identical topographic plotting. From a high position, the sides, on which toposequences are described, are generally short when they lead to first class drainage axis, and longer when they lead to upper-class axis. Strictly, speaking adjacent toposequences are then not really identical, the some being more extensive than the others. It is quite usual yet to consider them as identical because the soil-content is practically similar: only its extent being variable. On a long sequence, all the soils are present and well-developed; on a short one there are fairly often the same pedological differenciations, but they fill much more limited volumes. So, it is then possible to define representative sequences. New Caledonia shows, on the west coast, an hypertrophy of plains. In these conditions, they also represent morphological landscapes, which will not be distinguished by toposequences but "soil mosaics" (pedon juxtaposition which rules of space distribution are difficult to reveal).

Which are the proximate designation characteristics of landscapes ? They refer to engaged reliefs and certain particulars geomorphologic features. We can define for example : "a landscape of convex low hills derived from

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(1) - ESCHENBRENNER (V.), BADARELLO (L.), 1978 - Etude pédologique de la région d'Odienné (Côte d'Ivoire) - Carte des paysages morpho-pédologiques. Feuille Odienné 1/200.000 - Notice explicative n° 74 - ORSTOM - Paris.

coarse peridotitic materials" or a "landscape of plains derived from ancient and recent alluvial deposits". The soil-content is expressed with typological language by using its possibilities to reduce information. This soil-content will then be more synthetic than the one expressed for pedological segments.

In order to sum up these two paragraphs, it is possible to briefly define landscape and segments as follows :

. Landscapes regroup segments spatially and genetically set from top to bottom of the side. They can be compared to reduced topo-sequences, with which soil mosaics of wide-extended plains are associated.

. Segments are volumes wich gather some pedons characterized by a same dominent process of evolution or by several processes acting simultaneously, according to the same combined dynamic on the same material.

CARTOGRAPHY : MORPHO-PEDOLOGICAL MAP LEGEND

This legend presents soils in the different landscapes of the mapped area. We successively find :

- Landscape characterization : "Landscape of hills with sharp crests and steep slopes, derived from volcanogenic sedimentary rocks, associated with a landscape of plains derived from recent and ancient alluvial deposits"...

Then a schematic longitudinal section of the landscape on which are located the different cartographic units (U_1, U_2, U_3 ...) and the soils that constitute them. If certain soils and units are never present, this character is shown by the term "aleatory" (U_2 aleatory ... for example).

- Characterization of cartographic units and soils that composed them [1] : this characterization is developed in three different ways :

(1) BRABANT (P.), 1978 - Carte pédologique du Cameroun - Feuille de Béré au 1/100.000. Carte des contraintes édaphiques à 1/100.000. ORSTOM.

POSS (R.), 1982 - Etude morpho-pédologique de la région de Katiola (Côte d'Ivoire) - Cartes des paysages et des unités morpho-pédologiques à 1/200.000. ORSTOM - Notice explicative n° 76.

. In the left column (cartographic unit), by means of the graphic representation of soils which can be arranged in pedological segments (with 1, 2, 3 ... pedons) or in soil mosaics. In each case, the morphological characters of these volumes are specified (slope, erosion, external drainage, nature of material and variability).

. In the middle column (CPCS classification)[1], each soil or pedon of the cartographic unit is situated in the french system of classification.

. In the right column (soil typology), each soil or pedon of the cartographic unit is described in a synthetic way by means of the typological language (refer to definitions) which permits a precise diagnosis of the different horizons that composed the soils and draw their main characteristics. This column is to compare with the left one.
This diagnosis of the different horizons, which is found in the edaphic restraint map legend, is a bond between the two legends and permits one change from one to another without any difficulty.
In this way, it becomes extremely easy to connect analytical results with horizons, then to reconstitute soils and locate them in landscape.

CARTOGRAPHY : EDAPHIC RESTRAINT MAP LEGEND

This legend presents itself in tabular form with several parts.

1)- Restraints bound to landscapes.

Gathered in the left part of the table (7 columns), they concern :

- flood risks
- slope
- sensitiveness to erosion
- surface stoniness
- external drainage
- soil depth
- degree of variability (of soils).

(1) CPCS, 1967 - Classification des sols - ENSA - Grignon. 87 p. multigr.

Except for soil depth, restraints are estimated and several classes have been kept for every one.

- flood risks

  . null, weak { no or few restraints
  . medium : medium level of restraints (vigilance required)
  . high : high level of restraints

- slope

  . from null to very weak : 0 - 2 % { nor or few restraints
  . weak : 2 -10 %
  . medium : 10-30 % : medium level of restraints (vigilance required)
  . high : 30-50 %
  . very high : 50-100% { high level of restraints.

- sensitiveness to erosion

  . null, weak { no or few restraints
  . medium : medium level of restraints (vigilance required)
  . high, very high { high level of restraints

- surface stoniness

  . null : 0- 1 %
  . weak : 1-10 % { no or few restraints
  . medium : 10-30 % : medium level of restraints (vigilance required)
  . high : 30-50 %
  . very high : >50 % { high level of restraints

- external drainage

  . very slow, slow { high level of restraints
  . medium : medium level of restraints (vigilance required)
  . quick : no or few restraints

- soil depth

  . small : 5-40 cm : high level of restraints
  . medium : 40-80 cm : medium level of restraints
  . great : > 80 cm : nor or few restraints

- Degree of variability

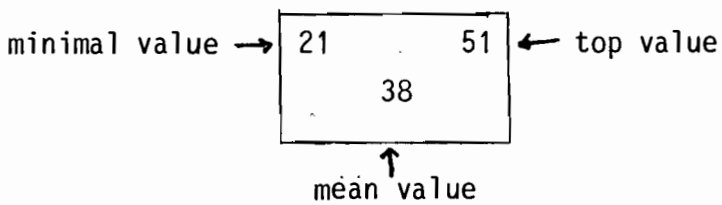
  It can be morphological (quick variations of soil depth, presence or absence of restraint horizons...) and chemical (quick and large variations of different cation contents, of texture ...).

  . weak : nor or few restraints
  . medium : medium level of restraints (vigilance required)
  . high : high level of restraints.

The following column represents the different cartographic units; their connection with those of the morphopedological map and their superficies.

2)- Restraints bound to soils (morphological and physico-chemical ones)[1]

They fill the right hand side of the table and are expressed horizon by horizon for each landscape. Indeed, the different types of horizons of the most frequently met soils in each landscape have been analysed. The mentioned values are generally mean ones. When it was possible, we have also entered extreme values :



We have then successively

- Depth

  . For apexol horizons : Humite, Melanumite, Verti-humite, Structichron, Entaferon (lutic and arenic), Vertichron

    . < 15 cm : high level of restraints
    . 15-25 cm : medium level of restraints (vigilance required)
    . > 25 cm : no or few restraints

  . For infrasols horizons : Leuciton, Lapidon, Entaferon (rudic), Oxidon-reducton, Reducton.

    . > 20 cm : high level of restraints
    . 10-20 cm : medium level of restraints (vigilance required)
    . < 10 cm : no or few restraints

- Coarse elements

  . < 15 % : no or few restraints
  . 15-30 % : medium level of restraints (vigilance required)
  . > 30 % : high level of restraints

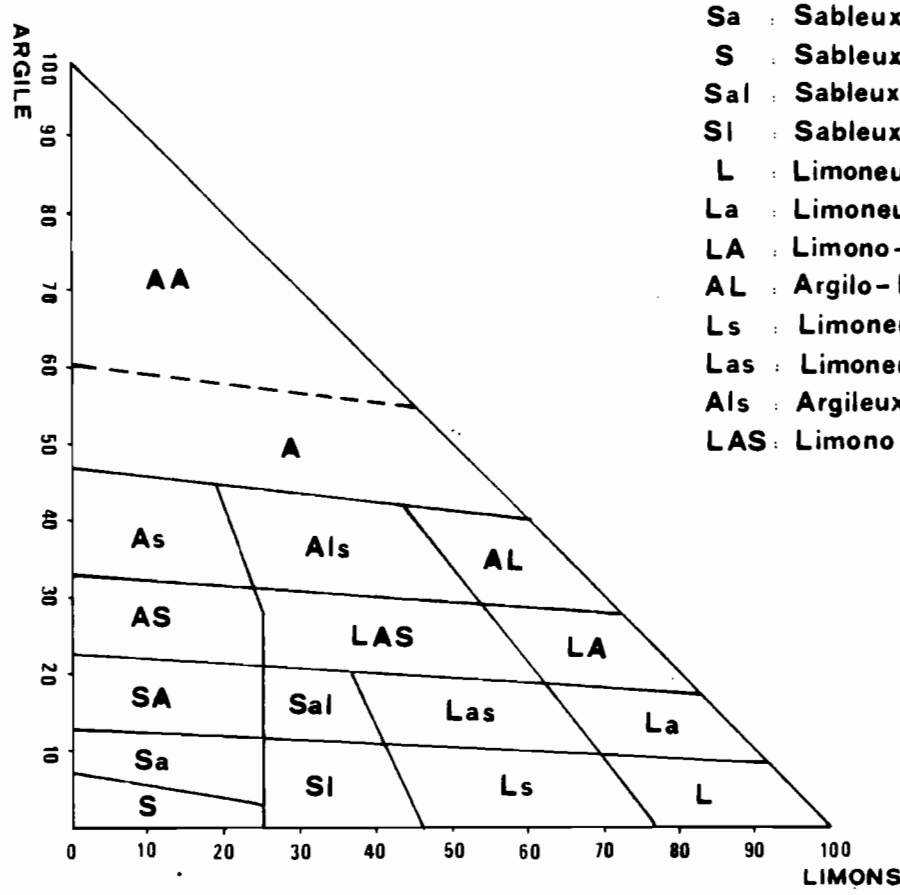
- Texture (refer to triangle - figure 1)

  . AA, S, Sl, L : high level of restraints
  . As, Sa, Sal, Las, Als, La, Ls, A { medium level of restraints
  . AS, SA, LA, AL, LAS : no or few restraints.

(1)-TERCINIER (G.), 1967 - Résultats d'analyses chimiques des terres. Mode d'interprétation spécialement adapté à la Nouvelle-Calédonie. ORSTOM-Nouméa.

-Memento de l'agronome - Ministère de la Coopération - Collection "Techniques rurales en Afrique" - Ed. 1980

-DABIN (B.), 1968 - Etude des facteurs de fertilité des sols tropicaux : Facteurs chimiques. in "Techniques rurales en Afrique" - ORSTOM - BDPA. Secrétariat d'Etat aux Affaires Etrangères. Paris. 278 p.



AA . Très argileux
A : Argileux
As : Argileux faiblement sableux
AS : Argilo-sableux
SA : Sablo-argileux
Sa : Sableux faiblement argileux
S : Sableux
Sal : Sableux faiblement argilo-limoneux
Sl : Sableux faiblement limoneux
L : Limoneux
La : Limoneux faiblement argileux
LA : Limono-argileux
AL : Argilo-limoneux
Ls : Limoneux faiblement sableux
Las : Limoneux faiblement argilo-sableux
Als : Argileux faiblement limono-sableux
LAS : Limono-argilo-sableux

TRIANGLE DE TEXTURE
(G.E.P.P.A.)

- External drainage (estimated

  . from null to slow : high level of restraints
  . medium : medium level of restraints (vigilance required)
  . quick : no or few restraints

- Water supply (différence between moisture pF 2,5 and moisture pF 4,2)

  . < 15 % : high level of restraints
  . 15-20 % : medium level of restraints (vigilance required)
  . > 20 % : no or few restraints

- pH

  . < 7,5 / . > 5,5 { high level of restraints
  . 5,5 -6 : medium level of restraints (vigilance required)
  . 6-7,5 : no or few restraints

- Organic matter :

. in humites	. in other horizons
. < 3 %	. < 1,5 % { high level of restraints
. > 8,5 %	. > 5 %
. 3-4,5 %	. 1,5-2 % : medium level of restraints (vigilance required)
. 4,5-8,5 %	. 2 - 5 % : no or few restraints

- Nitrogen

. in humites	. in other horizons
. < 1,2 ‰	< 0,6 ‰ { high level of restraint
. > 3,5 ‰	> 1,3 ‰
. 1,2-2,4 ‰	. 0,6-1 ‰ : medium level of restraints (vigilance required)
. 2,4-3,5 ‰	. 1-1,3 ‰ : no or few restraints

- C/N

. in humites	. in other horizons
. < 9	. < 8
. > 15	. > 14 { high level of restraints
. 13-15	. 12-14 : medium level of restraints (vigilance required)
. 9-13	. 8-12 : no or few restraints

- exchangeable calcium (me)

. in humites	. in other horizons
. < 3	. < 1 : high level of restraints
. 3-10	. 1-4 : medium level of restraints (vigilance required)
. > 10	. > 4 : no or few restraints

- exchangeable magnesium (me)

  . < 0,7 / . > 8 { high level of restraints
  . 4-8 / . 0,7-2 { medium level of restraints (vigilance required)
  . 2 - 4 : no or few restraints.

- exchangeable potassium (me)
  - . < 0,3 : high level of restraints
  - . 0,3-0,9 : medium level of restraints (vigilance required)
  - . > 0,9 : no or few restraints

- exchangeable sodium (me)

. in humites	. in other horizons	
. > 0,7	. > 0,9	
. 0,7-0,3	. 0,9-0,4	: medium level of restraints (vigilance required)
. < 0,3	. < 0,4	: no or few restraints.

- exchangeable aluminium (me)
  - . > 6 : high level of restraints
  - . 6-2 : medium level of restraints (vigilance required)
  - . < 2 : no or few restraints

- exchangeable capacity

. in humites	. in other horizons	
. < 5	. < 3	: high level of restraints
. 5-20	. 3-15	: medium level of restraints (vigilance required)
. > 20	. > 15	: no or few restraints.

- Saturation indice (with no account for exchangeable aluminium).
  - . < 40 % : high level of restraints
  - . 40-75 % : medium level of restraints (vigilance required)
  - . > 75 % : no or few restraints.

- Total phosphorus

. in humites	. in other horizons	
. < 0,5 ‰	. < 0,3 ‰	: high level of restraints
. 0,5-1,2 ‰	. 0,3-08 ‰	: medium level of restraints (vigilance required)
. > 1,2 ‰	. > 0,8 ‰	: no or few restraints.

- Assimilable phosphorus

  always < 0,02 ‰ : high level of restraints.

- Soluble salts (me)
  - . > 10 : high level of restraints
  - . 10-5 : medium level of restraints (vigilance required)
  - . < 5 : no or few restraints.

- Ca/T ratio (%)

. in humites	. in other soils	
. < 40	. < 30	: high level of restraints
. 40-60	. 30-50	: medium level of restraints (vigilance required)
. > 60	. > 50	: no or few restraints.

- Ca/Mg ratio

. in humites	. in other soils	
. > 10	. > 8	{ hight level of restraints
< 0,5	< 0,2	
. 0,5-1	. 0,2-08	: medium level of restraints (vigilance required)
. 1-10	. 0,8-8	: no or few restraints.

- Ca + Mg/K ratio

  . > 60 : high level of restraints
  . 60-30 : medium level of restraints (vigilance required)
  . < 30 : no or few restraints.

- Mg/K ratio

  . > 30 : high level of restraints
  . 30-5 : medium level of restraints (vigilance required)
  . < 5 : no restraints.

- Al/Al + S ratio (%)

  • > 50 : higl level restraints
  • 50-10 : medium level of restraints (vigilance required)
  • < 10 : nor or few restraints.

- N/total P_2O_5 ratio

  . > 4 (lack of P) { high level of restraints (unbalance)
  .2< (lack of N)
  . 2-4 (lack of P and N) : medium level of restraints (vigilance required).

- Na/T ratio

  • > 10 : high level of restraints
  • 5-10 : medium level of restraints (vigilance required)
  . < 5 : no or few restraints.

These different classes of restraints have been defined from works of TERCINIER (1967) and DABIN (1968).

CARTOGRAPHY : UTILIZATION OF THE EDAPHIC RESTRAINT MAP AND ITS LEGEND(1)

There are two types of units (C_1, C_2, C_3...) in the restraint-map :

- complex units regrouping several units of the morphopedolofical map

$C_1 = U_1 + U_5$

$C_6 = U_7 + U_8 + U_{19}$.

These regroupings have been formed because the soils of these different units present a lot of similar morphological and/or physico-chemical characteristics.

- simple units corresponding to a single unit of the morphopedological map :

$C_2 = U_2$

$C_3 = U_3$

(1) - BEAUDOU (A.G.), FROMAGET (M.), BOURDON (E.), PODWOJEWSKI (P.), 1983 - Carte des contraintes édaphiques de Tontouta.

Simultaneously we mention the pedons which are analysed in each unit :

ex. : - in unit C_1 : pedons 1 and 2
- in unit C_3 : pedons 1, 2 9

For each unit of the restraint map, analysed diagnostic horizons are indicated. These same horizons, named by the typological language, are met again in the morphopedoligical map legend (column : soil typology)..

How can we go from the column "soil typology" (morpho-pedological map) to the column "disgnostic horizons" (restraint map) ?

Let us choose, for example the unit U_3 (morpho-pedological map) which corresponds to the unit C_3 (restraint map).

- in this unit C_3, we have admitted 9 pedons all of which have been analysed. We can write them in the following way :

Pedon 1 : HUMITE, MELANUMITE - Humo-VERTICHRON - ENTAFERON-VERTICHRON
Pedon 2 : HUMITE, MELANUMITE - Verti-HUMITE - ENTAFERON-VERTICHRON (Gy)
Pedon 3 : HUMITE, MELANUMITE - Verti-HUMITE - ENTAFERON-VERTOCHRON (Ca)
Pedon 4 : HUMITE, MELANUMITE - Humo-VERTICHRON - ENTAFERON-VERTICHRON (Mg)
Pedon 5 : HUMITE, MELANUMITE - VERTICHRON humic - ENTAFERON-VERTICHRON (Mn)
Pedon 6 : HUMITE - VERTICHRON humic - ENTAFERON-VERTICHRON (Mn + Gy)
Pedon 7 : HUMITE, MELANUMITE - VERTICHRON (Ca) - ENTAFERON-VERTICHRON (Ca + Gy)
Pedon 8 : HUMITE, MELANUMITE - VERTICHRON (Mn) - ENTAFERON-VERTICHRON (Mn + Mg)
Pedon 9 : HUMITE, MELANUMITE - VERTICHRON (Mn - ENTAFERON-VERTICHRON (Ca + Mn)

Apexol | Infrasol

These descriptions show us that the apexol is always composed of a melanumite and/or an humite, followed in most of the soils by a Verti-humite (a term which regroups the diagnosis humi-vertichron, verti-humite, vertichron-humic. These different diagnosis always show the presence, in the same horizon, of vertic and humic characteristics. The importance of one in relation to the other makes the difference).

In these conditions, we can say that, in the apexols of this unit, either one, or two, or all the following disgnostic horizons are present :

HUMITE - MELANUMITE - Verti-HUMITE.

It is then possible to regroup all the analysis related to these three horizons, and to calculate mean values for all the soil types.
All of which is indicated in this legend. These mean values are generally enframed by extreme minimal and maximal values (when the number of analysis was sufficient). Let us take for example the horizon depth :

MELANUMITE	16	37	57
HUMITE	15	32	58
Verti-HUMITE	12	24	56

The extreme values give information about the variability of physico-chemical characters in a seme pedon of these soils.

By contrast, at the level of infrasoil, the variations are much greater. Each horizon presents a different characteristic. We have then conserved the nine horizon types described in this region :

ENTAFERON - VERTICHRON	
ENTAFERON - VERTICHRON (Gy)	(occurence of gypsum)
ENTAFERON - VERTICHRON (Ca)	(occurence of limestone)
ENTAFERON - VERTICHRON (Mg)	(occurence of magnesium)
ENTAFERON - VERTICHRON (Mn)	(occurence of manganese)
ENTAFERON - VERTICHRON (Mn-Gy)	(occurence of manganese and gypsum)
ENTAFERON - VERTICHRON (Gy-Ca)	(occurence of gypsum and limestone)
ENTAFERON - VERTICHRON (Mg-Mn)	(occurence of magnesium and manganese)
ENTAFERON - VERTICHRON (Ca-Mn)	(occurence of limestone and manganese).

The same as for apexols and when it was possible, we have calculated mean values , for each horizon of each soil type. Results are always expressed in the same way.

This synthetic and analytical proceeding allows us to give, for each restraints map unit, a list of present disgnostic horizons. In the unit C_3 for example :

MELANUMITE
HUMITE
Verti-HUMITE
ENTAFERON-VERTICHRON
ENTAFERON-VERTICHRON (Gy)
ENTAFERON-VERTICHRON (Ca)
ENTAFERON-VERTICHRON (Mg)
ENTAFERON-VERTICHRON (Mn)
ENTAFERON-VERTICHRON (Mn-Gy)
ENTAFERON-VERTICHRON (Gy-Ca)
ENTAFERON-VERTICHRON (Gy-Mn)
ENTAFERON-VERTICHRON (Ca-Mn)

Other units can be much more simple : particularly C_1 can be characterized in the following way :

HUMITE
HUMITE vertic
ALTERITE

The list of different unit horizons is not comprehensive, for certain pedons were sometimes only observed and not analysed owing to their little importance. So, by working in the field, the pedologist or other user will be able to rapidly characterize the soils that he meets :

- the first operation consists of taking one's bearings of the morpho-pedological map and then locating the soil in its landscape.
- After that, he has to identify the series of diagnostic horizons and then to refer to the list of horizons given by the restraint map legend, in order to know the physico-chemical characteristics of horizons and soils in this landscape.

If we always remain, for example, in the cartographic unit C_3, we can observe in the field different types of profiles such as those characterized by the following succession of horizons :

- MELANUMITE, Verti-HUMITE, ENTAFERON-VERTICHRON (Ca), ENTAFERON-VERTICHRON (Gy)

or

- HUMITE, ENTAFERON-VERTICHRON.

etc...

Many possibilities can occur, but in most cases, we shall be able to refer to the list of diagnostic horizons described in the map.

The typological diagnosis part then becomes fundamental :

- it allows a quick and accurate identification of pedological horizons in the field;
- it allows an easy processing of pedological data (observation, analysis, synthesis).

- Principally, it allows to connect field observations and soil physicochemical data, and to pass without any difficulty from the morpho-pedological map legend to a restraint legend. It is a manner of connecting landscapes, soils and their physicochemical characters and then better valorizing the different results of pedologists.