MICRO-ORGANISATION OF LOOSE FERRALLITIC MATERIALS IN
THE CAMEROONS

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Agronomique de Nkolbisson, BP 2017, Yaoundé, Cameroon)

ABSTRACT

In the Cameroons, loose clay horizons which occur on
the relict indurated formations are often several metres-

thick. They are generally homogeneous from the geo-
chemical, mineralogical and physico-chemical points of
view and are distinguishable from one another mainly by
their colour and their organisation. The vertical sequence
of organisation is the morphological expression of two
opposing pedogenic processes:

- A process of organisation involving microstructura-
tion by reticulation of the original clay plasma, which
affects the deep, red and dense horizons.

- A process of disorganisation resulting from
discolouration, plasmic microlysis (or 'crumbling' of the
microstructures) and disturbance of the a-matrix (with
clay eluviation). These three mechanisms, acting either
together or successively, affect the upper part of the
profiles.

The relative development of these two processes is
variable. Moreover, it is not possible to define a
strict chronology since the weak state of organisation
of the upper horizons could be inherited partly from the
original pedoplasmation.

INTRODUCTION

About two-thirds of the Cameroons is covered by
ferrallitic soils with a long and complex history
(Fig. 1). Unlike many other African countries, particu-
larly those in western Africa (d'Hooore, 1954), except
in rejuvenated zones (Segalen, 1967; Martin, 1967,
1970; Muller, 1979), relict indurated formations in
the Cameroons generally occur below a loose clay formation.
From a chemical point of view, the profile is fairly homogeneous (Morin, 1973). Goethite, hematite, and iron oxides are the main hydrous Fe oxide minerals, while clay minerals are almost completely absent. The carbon content is very low and the horizons are of Type D (strongly weathered). The macro- and meso-organic carbon content is very low.

The macro-organic carbon content has been based on microscopic analyses of the profiles (geological microscope). The organic content is very low. It has been based on the existence of 'yellow' soil profiles (Fig. 2). A microscope study of the soil profiles (Fig. 2) has revealed the existence of a macro-organic layer, which has been divided into two sublayers:

1. The group of peats (Fig. 2a). It includes weakly contrasting horizons.
2. A lower horizon, which is divided into two sublayers:
   a. Deep (Fig. 2a). It includes weakly contrasting horizons.
   b. A layer of coarse blocky structure within the lower horizon.
several metres thick (Muller, 1975).

From a geochemical, mineralogical and physico-chemical point of view, this loose clay formation is fairly homogeneous over the south Cameroons plateau (Morin, 1979). The clay fraction is kaolinitic; goethite, hematite and, to a lesser extent, gibbsite are the main hydroxides and oxides; the skeleton grains are almost exclusively quartzose; primary minerals, other than some heavy minerals, are entirely transformed; the horizons are strongly leached of exchangeable bases (strongly unsaturated soils (C.P.C.S., 1967)).

The macroscopic study of this loose formation has been based previously on observation of shallow profiles (generally less than 2m deep). Because of the weak contrast in structure between horizons and the relative uniformity of texture throughout, classification of the soils at intermediate taxonomic levels (suborders) has been based on colour ('red', 'grey ferruginous' and 'yellow' soils).

Observations made on sections (Bocquier and Muller, 1973) or deep profiles reveal a more or less pronounced vertical colour gradient from lower to upper horizons (Fig. 2). Moreover, detailed examination, e.g. with a microscope, shows typical horizons and volumes and the existence of specific structural organisations. The macro- and micromorphological components of this loose layer are examined in this paper.

VERTICAL ORGANISATION IN THE LOOSE LAYER

Five horizons are recognised in the material, divided into a lower and an upper group (for full descriptions, see Muller, 1977a and b).

1. The group of lower horizons is characterised by weakly contrasted colours and diffuse boundaries (Fig. 2a). It includes from the base of the section upwards:

(a) Deep dense horizons

Macromorphology: These are the reddest horizons within the layer with Munsell hues of 10R. Other properties include clay texture, moderately developed coarse blocky structure, compact and firm consistency
Fig. 2. Diagram of the vertical evolution of loose horizons.
and an apparent low porosity.

Micromorphology: Few randomly distributed quartz grains; weakly oriented argillasepic plasmic fabric with a few insepic patches (Fig. 3a), gradually becoming insepic upwards with heterogeneous masepic patches; some plasma separations surrounding and delimiting micropeds (50-200μm) between crossed polarisers; microporosity composed of micro-fissures and scattered meso- and orthovughs; few aggrotubules.

Fig. 3(a) Red, dense deep B horizon. Weakly insepic plasma. Isolated microvoids; (b) Horizon including dense and microstructured phases. Strongly expressed plasmic fabric (in-lattisepic) bordering a void (top left). Strongly birefringent plasma separations. Differentiated micropeds are contiguous on a local basis. Some small peripheral fissures. Structured and darker plasma lower right; (c) Horizon similar to (b). Contrasted micropeds partly or totally separated by micro-fissures which anastomose in the form of a star; (d) Microstructured horizon. Interpedal micro-fissures evolve into a granular fabric.
(b) Horizons with mixed dense and microstructured areas

Macromorphology: Dense red phase (c. 10R) continuous with underlying dense horizon; more organised than underlying dense horizon; finer but still compact structure; some dense areas of very low porosity; gradual boundary to a blocky phase with fine to very fine peds; less red in colour (2.5YR); more or less loose structure; very porous; friable to very friable.

Micromorphology: The dense phase has a mainly insepic, and the granular phase a ma-in-lattisepic, plasmic fabric (Fig. 3b); micropeds, more numerous than in the horizon below, are also more discrete; micropeds tend to be more contrasted with the surrounding matrix due to the surrounding plasma separation being lighter coloured and more birefringent than the matrix; near the top of the horizon the microstructuration becomes more developed; micropeds are partly or totally separated by microfissures which anastomose in the shape of a star (Fig. 3c).

(c) Microstructured horizons

Macromorphology: Red to yellowish red (2.5YR-5YR); strongly developed microgranular structure and large porosity; very friable; little dense matrix, occurring as rounded bodies (clay nuclei) a few µm to a cm in diameter.

Micromorphology: Skeleton similar to deeper horizons; more strongly expressed plasmic fabric (in-volattisepic); dense network of fissures increasing upwards to develop a reticulate pattern (Fig. 3d); abundant rounded micropeds with sharper contrast than in horizons below due to further discolouration of surrounding plasma separations; strong pedoturbation; few clay nuclei (Fig. 4a), with weakly insepic or asepic plasmic fabric.

2. The group of more or less contrasted horizons affected by organic accumulation shows a diffuse or gradual transition to the deeper horizons described above (Fig. 2b and c). They include:
Fig. 4. (a) Microstructured horizon. Areas of apedal and isotic plasma are separated in 'clay nucleii' (left) within a strongly microstructured matrix subjected to pedoturbation (right); (b) 'Consistent' horizon. Compact with a weakly insepic plasmic fabric. Composed of long fissures. Ferri-argillans with simple or zoned voids; (c) Humus horizon. Abundant quartzose skeleton grains. Quasi-isotic structure. Irregular and interconnected meso- and macro-vughs.

(a) 'Consistent' B horizons

Macromorphology: More or less darkened by organic matter throughout and/or on the faces of aggregates; red to yellow plasma (2.5YR to 7.5YR); clayey to sandy clay; medium to coarse compact blocky structure; moderate porosity, distinct to sharp upper boundary.

Micromorphology: Degree of development of the plasmic fabric decreases upwards from ma-insepic to weakly insepic to locally isotic in the upper part and in lighter pockets; fewer micropeds than in underlying horizon and less discrete; some patches of redder plasma decreasing upwards in number and size; porosity mainly in the form of ortho- macro- and mesovughs and some vertically
oriented ortho-fissures; simple and complex continuous and zoned ferri-argillans and organo-argillans along microfissures, thickest in vertical fissures (Fig. 4b).

(b) **Humus horizons**

**Macromorphology:** Yellowish red to dark yellow (5YR to 10YR) stained by organic matter; clayey sand to sandy clay; subangular to nodular blocky structure; loose; porous; very friable.

**Micromorphology:** Abundant quartzose skeleton; weakly insie plicastic fabric becoming aspecific in yellower parts; no micropeds; agglomeroplastic related distribution; many ortho- meso- and macrovughs strongly interconnected by ortho-fissures (Fig. 4c); number and size of organo- and ferri-argillans decrease upwards; no argillans in the uppermost part.

**MECHANISMS RESPONSIBLE FOR ORGANISATION**

Apart from the gradients in colour and texture, which are generally weak, the horizons are distinguished mainly by their structure. The continuous vertical study indicates two main mechanisms:

**Mechanisms of organisation**

In the lower part, the gradual evolution from red compact, firm, rather impervious phases to very porous, very friable microgranular phases is associated with the gradual development of a blocky structure in which the discreteness of the units increases and size decreases upwards.

This fractionation which is visible macroscopically as well as microscopically, corresponds to microstructuration and the genesis of microped organisations. It begins with a simple change in plasmic fabric without change in colour, followed by further reticulation of the matrix and modification of the original plasmic fabric as fractionation proceeds.

This structuration becomes more marked upwards, developing ultimately through peripheral microfissures into a granular fabric. Part of the matrix remains resistant to microstructuration and residual clay nuclei, corresponding to original B horizon material, remain even
Mechanisms of disorganisation

Three phenomena are observed in the upper part of the profiles:

(a) Discolouration of the plasma (i.e. change from reddish to yellowish colour): The first signs of colour change observed in thin sections are in samples from deep in the profile. The change is noted in fine lamina in the weakly structured soil material. Macroscopically, the change in colour is only clearly visible in the upper part of the profile. The observed colour gradient varies in intensity and extent (Fig. 5). The change in colour is probably related to decomplexing within the original plasma (Segalen, 1969).

Fig. 5. Structural phases in two horizons of a red soil which is discoloured in its upper part (profile GOY344).
(b) Concentration of the plasma in the consistent horizons:
This affects all the ferrallitic soils but it is more intense and widespread the more marked the change in colour from red to yellow. It is possible, especially in soils that are red to the surface, that this concentration is partly relict, i.e. inherited from previously deeper red B horizons. However, it also seems to characterise situations in which there is fusion of microstructure together with discoulouration (microlysis: Muller, 1977b). Associated with discrete and localised discoulouration is an attenuation of the birefringence of plasma separations which becomes more marked towards the surface.

(c) Instability of the soil material: The material becomes more unstable in the yellower 'microlysed' upper horizons. There is dispersion of the plasma which is translocated into the 'consistent' B horizons leaving a relative accumulation of quartzose skeleton in the humus horizons.

There is thus a clear correlation between the evolution of the morphological components - colour, structure and texture. Increasing colour change from redder to yellower colours is associated with more intense microlysis which facilitates translocation of clay.

CONCLUSIONS
The differentiation of clayey material in many ferrallitic soils in the Cameroun is highly dependent on the relative development of two pedogenic processes which develop from lower toward upper parts of a profile. One is a factor of organisation, the other one of disorganisation.

There is an evident connection between the phenomena of discoulouration, plasmic microlysis and leaching, characteristic of the disorganisation process in the upper horizons.

It is difficult to establish a strict chronology for the two processes. Traditionally, a continuous vertical connection is inferred particularly when the transition between horizons is gradual, each horizon being assumed to form by direct transformation of the underlying horizon.
horizon. Observations above suggest that the vertical sequence of organisation is not systematically linked to a particular sequence of pedological events, i.e. micro-structuration followed by microlysis. Compact red original material with poorly developed plasmic fabric (argillasepic, insepic) can occur in microstructurally developed horizons even near the surface in a state close to the original.

Nevertheless the two processes oppose each other. One is an agent of stability producing structural units resistant to degradation. The other destroys the initial structure and eventually causes disturbance of the soil material.

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Soil Micromorphology
VOLUME 1
Techniques and Applications

Edited by
P Bullock and C P Murphy
Rothamsted