WEATHERING AND DEVELOPMENT OF CHEMICALLY MATURE SOILS

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Keywords: bauxite, ferricrete (iron crust), Gondwanean cratons, hydrolysis, laterite, Oxisol (Ferrasol), pedoplasmation, stone line, Ultisol (Acrisol), weathering.

Contents

Summary

Chemically mature soils are the result of a long and complex genesis. A large set of soil-forming processes, as well as erosional and accretional processes, contribute to the

transformation of silicate bedrocks into such soils. The depth of weathering is related to time, although the impact of soil forming processes has fluctuated widely through time in relation with climate variations. Chemically mature soils, termed *laterites* by geologists, occur mainly on stable Gondwanean cratons.

The transformations begin with bedrock weathering, i.e., hydrolysis of all silicates, of which the main end products, depending on the soil drainage, are alumina, e.g., gibbsite, or clays, the most common being kaolinite. At this stage, the bedrock texture is preserved. During the next stage, the rock texture disappears while secondary minerals and resistant residual primary minerals are incorporated into the soil matrix, in a process named *pedoplasmation*, factors of which are groundwater action, faunal burrowing, and clay illuviation. Low redox groundwaters played an important role in these soils, creating a thick hydromorphic horizon (the mottled clays), while iron oxides are concentrated in the zone of fluctuation of groundwater in the form of nodular horizons or iron crusts (ferricretes). Mobile groundwater eluviates (micro-erodes, transports, and sorts particles and grains) in the mottled clays and to a lesser extent in iron crusts.

Subsurface horizons; oxic, kandic, and, to a lesser extent, argillic horizons; usually have the same mineralogical composition as the weathered bedrock, but are considerably enriched in sesquioxides. The genesis of oxic and kandic horizons is not yet fully deciphered. Presently, the functioning of these horizons is dominated by the soil biota.

Through time, groundwater has moved up and down in relation to cyclical variations in precipitation, leading to alternate aggradation and degradation of iron oxides. The up-and-down movements of the groundwater were interrupted at certain points by erosional phases during which ferruginous nodules were transported on slopes while allochthonous materials, basically aeolian, were also added to these soils during certain periods.

Chemically mature and derived soils are affected by severe constraints for modern agriculture, i.e., very low chemical fertility; moreover these soils are frequently characterized either by waterlogging, or by a low water-holding capacity—and in the case of some soils, by both. They are also very sensitive to degradation when modern techniques are applied without caution, causing erosion, hard setting, and soil biota degeneration. Poorly controlled irrigation can lead to a rise in the ground water table, which will induce salinization or alkalinization. In the past, most of these soils were to be found under virgin forest while only a few were cultivated, either by a system of long-term fallow, or with cultivated plants growing under a forest canopy. Both systems were undoubtedly sustainable. New systems of sustainable cultivation of such soils (e.g., no tillage) are presently being experimented with.

1. Introduction

As soon as continents were formed at the very beginning of Earth's development, long before life appeared, surface rocks began to be transformed into secondary products, basically clays, as a consequence of rainfall. Later, when life appeared on the emerged lands, an ecosystem developed in these secondary products leading to the formation of soil profiles. At present, thick, chemically mature, complex, ancient soils (also named laterites) formed by long-term chemical weathering of crustal bedrock cover over one third of all emerged lands, principally on cratons belonging to the Gondwana megacontinent.

From a scientific viewpoint, the chemically mature soils must serve for the long term as a sensitive environmental sensor at the interfaces of atmosphere, biosphere, and lithosphere on continents. The concentrations of sesquioxides that are very common in these soils provide surface geochemists and paleoclimatologists with very valuable, unique information on the past environments of continents.

Chemically mature soils are mainly located in the tropics, some in the subtropics. Before the recent human exponential expansion, these soils were covered by virgin rainforests and savanna. Native communities cultivated only restricted surfaces using the very conservative system of slash and burn followed by a long-term fallow (30–40 y). Nowadays, most of the rainforests and savanna have been definitively cleared. After clearance, unadapted techniques of plowing and cultivation have most commonly been applied, as in Brazil. Consequently, wide areas of chemically mature soils are irremediably lost since all these soils when cleared are in danger of an irreversible loss of fertility by erosion, compaction, degradation of the soil ecosystem, and nutrient lixiviation. Agronomists are presently working in Australia, Brazil, and India on sustainable systems of cultivation that grant high yields with conservative practices. To achieve their tasks, they need basic knowledge of the genesis and the functioning of these soils. For instance, in the Sahel, erosion due to natural processes that occurred in the geological past has to be clearly separated from recent human-induced erosion.

These soils also serve as mineral sources, predominantly of aluminum, but also of nickel, cobalt, manganese, gold, and palladium (e.g., the soils of the Yilgarn craton in Western Australia). Mining soils that bear useful elements destroys the soil cover, produces large amounts of waste, and generates pollution such as mercury pollution in the mining of gold.

Chemically mature soils have been investigated on the one hand by mining geologists, whose research has mainly been devoted to the lower part of these soils where mineable elements are located, and on the other hand by soil scientists who have thoroughly studied their upper part because of their important fertility constraints. This chapter is an attempt to combine both viewpoints in order to explain the genesis of these soils and the evolution of related soil covers.

2. Morphology and Classification of Chemically Mature Soils

Chemically mature soils that developed upon the igneous, metamorphic, or volcanic bedrock of Gondwanean cratons consist of two main compartments, the alterite in which the bedrock texture is preserved, and the soil profile characterized by various soil matrices and horizons (see Figure 1).

2.1. Alterites

The alterite begins with a front of weathering, which is very irregular—the bedrock becomes divided into unweathered volumes of various sizes and shapes which are isolated from their neighbors by weathered material. The partly weathered bedrock is commonly thin on Gondwanean cratons, but thick in midlatitudes.

The alterite then consists of a thick isoalterite (from a few to some tenths of meters) in which the bedrock texture is preserved (Figure 3), but all common primary minerals are completely transformed into secondary ones, except quartz (which is partly altered: Figure 4) and very resistant minerals such as zircon and rutile. The bulk density decreases upwards due to a porosity increase.

Then, progressively or abruptly, the isoalterite is either replaced by an alloterite in which the bedrock texture is no longer perceptible, or overlaid by soil horizons.

Morphological diversity of alterites depends on bedrock composition, a possible hypogene (hydrothermal) weathering prior to the supergene weathering, the duration of exposure, and geographic location.

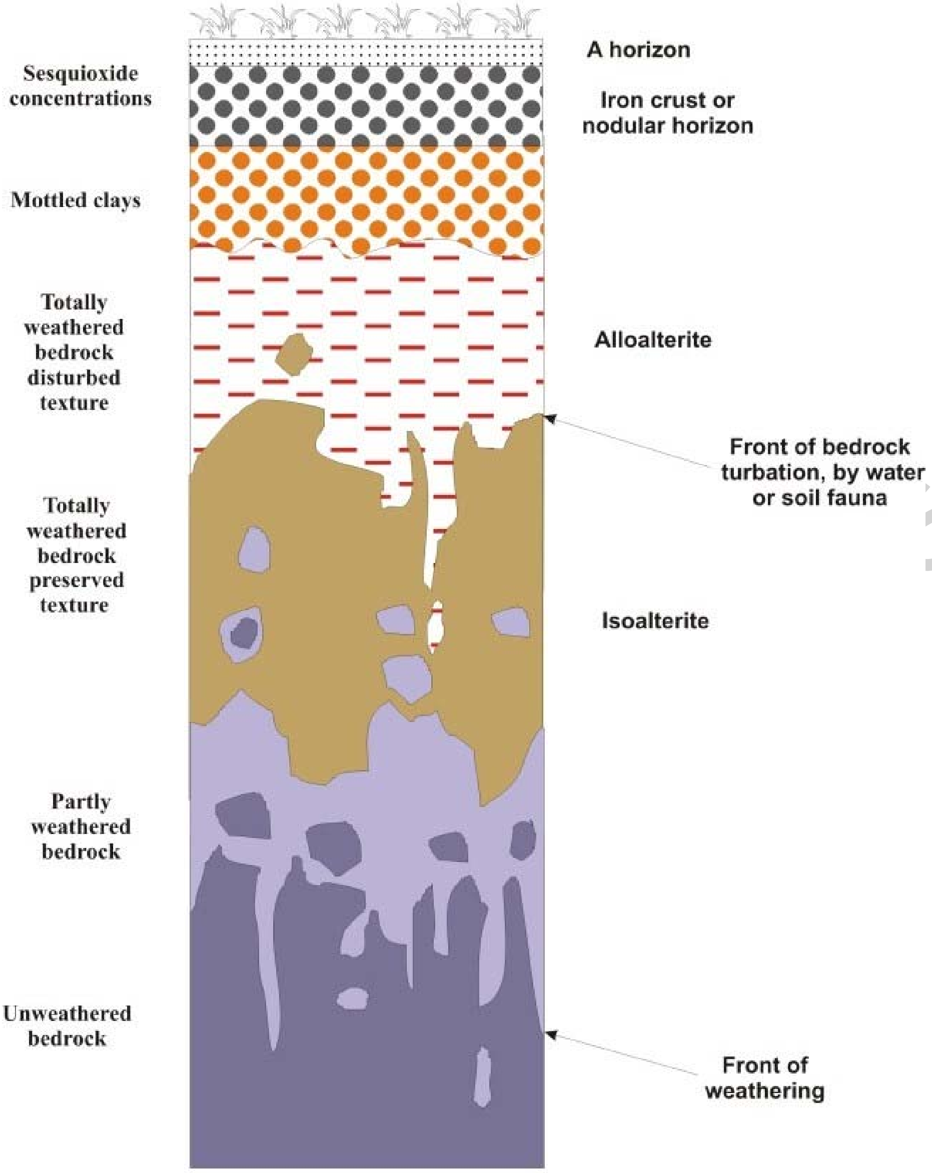

Figure 1. Schematic profile of a typical chemically mature soil (laterite)

The integration of isalteritic materials into the soil matrix, called pedoplasmation, is the result of various processes (e.g., groundwater eluviation) clay illuviation (Figure 5), or faunal activity, which in the end produces a homogeneous soil matrix.

Alterites have not been taken into account by soil classifiers who consider them merely as a parental material. They can be classified according to the nature of the parental bedrock, the degree of weathering, or the number and type of weathering phases present.

2.2. Chemically Mature Soils: Diagnostic Horizons and Characters

A large variety of soil profiles exist, either overlying alterites, or developed on pedo-sediments, which originate from alterites or chemically mature horizons. However, in these profiles, only a restricted number of diagnostic horizons and characters have been recognized. Chemically mature soil profiles result from various combinations of these diagnostic horizons and characters (Figure 2) which are as follows:

Concentrations of sesquioxides (goethite, hematite, and magnetite, as well as gibbsite and boehmite and oxides of manganese and titanium) are undoubtedly the main character of the soil compartment of chemically mature soils (e.g., Figure 2.1 through 2.5).

The US Soil Taxonomy considers only three diagnostic characters which are supposed to function at present: (a) aquic conditions identified in the field by initial sesquioxide aggradations (see ***Soils***) (e.g., ferruginous coatings, root pseudomorphs, mottles, and depletions (bleached zones)); (b) plinthite (from Greek *plinthos*, brick), an iron-rich soil matrix which hardens when exposed to repeated wetting and drying (Figure 2.2 through 2.5 and Figure 3.7); (c) petroferric contact, where only the boundary is taken into account, not the iron crust itself. The WRB accords more importance to sesquioxidic concentrations than does the US Soil Taxonomy. A horizon characterized by well-developed mottles within an iron-depleted matrix is for the WRB a ferric horizon (from Latin *ferrum*, iron). When the amount of mottles reaches 10% or more and they harden irreversibly, the horizon is considered to be a plinthic horizon (Figure 3.7). Petroplinthite (from Greek *petros*, rock and *plinthos*, brick) is a WRB diagnostic horizon characterized by a continuous iron oxide indurate layer (Figure 2.1 and Figure 3.5) while Plinthosols are a WRB reference soil group (Figure 2.1 and 2.2). However, many sesquioxidic concentrations are not taken into account in soil classifications, as they should be because they behave as inert, inherited constituents. Nodular horizons (Figure 2, Figure 3.3 and 3.4) and iron crusts (Figure 2.1, Figure 3.5 and 3.6; synonymous with ferricrete and ironstone) are not mentioned in existing soil classifications.

A comprehensive typology of sesquioxidic concentrations requires thin section investigations completed by elemental microanalysis: naked eye observations are not sufficient. Existing diagnostic horizons and characters should be augmented by adding the following horizons:

Nodular horizons: These consist of discrete nodules of various forms and origins (Figure 3.3, 3.4, and 3.5) which should be classified as: (a) primary ferruginous nodules which can be subdivided according to the host material into the subcategories of *lithomorph* (weakly to moderately weathered bedrock), *alteromorph* (completely weathered individual mineral or bedrock), *aquamorph* (iron oxide impregnated mottled clays), *oximorph* (iron oxide impregnated oxic matrix), and *vegetamorph* (iron oxide impregnated charcoal fragment (Figure 5.8); (ii) super-ferruginous nodules subdivided according to the host material (if recognizable) and if appropriate according to the presence of other secondary minerals such as gibbsite (Figure 5.7); (iii) cortified nodules subdivided according to the number of cortices and their color (Figure 3.4 and Figure 5.8). Some types of nodular horizons are shown in Figure 2 (2.2, 2.3, 2.4, and 2.9).

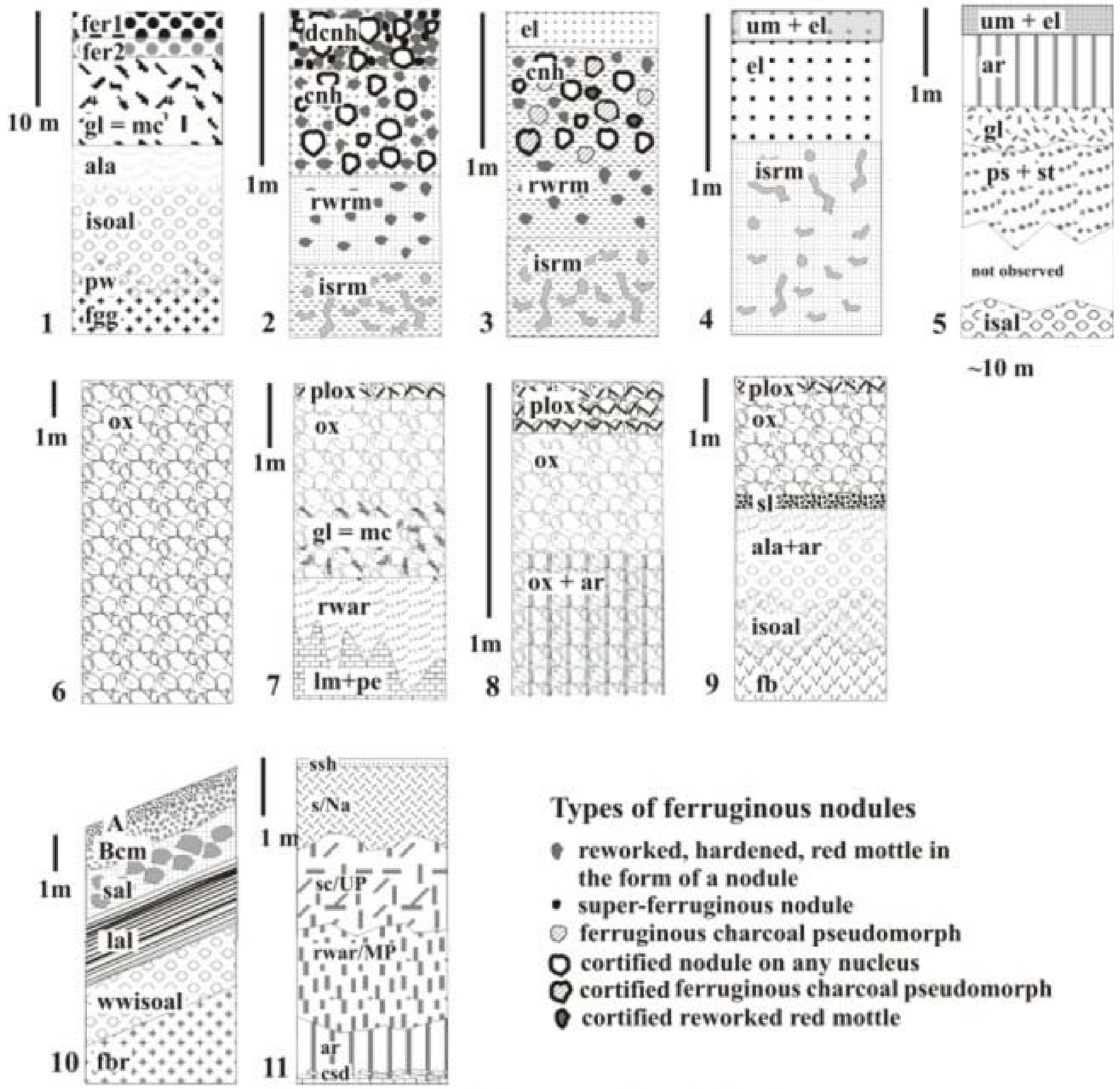

Figure 2. Some chemically mature and derived soil profiles (1 through 8) Comparison with Mediterranean and midlatitude complex soil sections (9 and 10). (1) Extremely developed chemically mature soil profile dating back to the Tertiary and even earlier. Highest geomorphic surface of Liptako (north of Niamey, Niger). Fer1: very hard ferricrete. Fer2: transition to mottled clays, ferricrete becoming progressively softer. Gl = mc: mottled clays. Ala: alloalterite. Isoal: isoalterite (see Figure 3.1). Pw: partially weathered zone. Fgg: fresh granito-gneiss. (2) Well-developed chemically mature soil profile, Plinthaquult (US Soil Taxonomy). Flat, midslope surface of Youth Island, Cuba, near the airport. Dcnh: dense, complex, nodular horizon, sandy matrix with well expressed eluvial characters. Cnh: complex nodular horizon. Rwcm: reworked red mottles. Isrm: *in situ* red mottles. This profile is developed on a kaolinic clay pedo-sediment. (3) Moderately well developed chemically mature soil profile, Plinthaquult (US Soil Taxonomy). Flat, lower mid-slope surface of Youth Island, Cuba. El: eluvial, sandy, horizon. Cnh: complex nodular horizon. Rwcm: reworked red mottles. Isrm: *in situ* red mottles. Like profile 2, this soil is developed on a kaolinic clay pedo-sediment. (4) Monophased hydromorphic soil developed on sandy material originated from chemically mature soils. Lower slope of Youth Island, Cuba. Um + el: umbric epipedon

with well expressed eluvial characters. El: eluvial horizon. Isrm: *in situ* red mottles. (5) Aquic Kandihumults developed on coastal sediments, Middle Pleistocene in age. Southwest coast of Mexico, Gulf of Mexico, near the city of Cardenas. Um + el: umbric epipedon with eluvial characters. Ar: clay rich horizon with few illuvial features (kandic). Gl: gleyed horizon. Ps + sl: pedo-sediment and reworked, quartzic gravels in the form of stone lines. Isal: completely weathered, except for quartz, *in situ* cobbles. (6) Thick, undifferentated Oxisol (Queensland, Australia; see Figure 4.8). (7) Aquic Eutrodox (Havana plain, Cuba; see Figure 3.7). Plox: ploughed surface layer. Ox: oxic horizon. Gl = mc: mottled clays. Rwar: reworked soil material with very abundant argillans. Lm + pe: limestone with abundant peridotite fragments. (8) Oxisol (Havana plain, Cuba). Plox: plowed surface layer. Ox: oxic horizon. Ox + ar: clay illuviation in the form of coatings and infillings superimposed on a compacted oxic fabric. (9) Oxisol (province of Misiones, north of Argentina). Plox: plowed surface layer. Ox: oxic undifferentiated mass. Sl: stone line consisting dominantly of ferruginous nodules. Ala + ar: partially reworked alterite mixed with clay coatings. Isoal: isolaterite. Fb: fresh basalt. (10) Typical section on granite of Western Europe (Brittany, area of Quintin, France; see Figure 4.9). The upper meter is characterized by a Dystrudept (US Soil Taxonomy) which corresponds to the present-day pedogenesis. A: ochric epipedon. Bcm: cambic B horizon. Fossil periglacial characters. Sal: stony alterite. Lal: lamellar alterite. Wwisoal: weakly weathered isoalterite (lixiviation of K^+ and iron exudation from biotites and serecitization of feldpars). Fbr: fresh bedrock. (11) Section of juxtaposed paleosols and pedo-sediments lying on a coastal calcarenite Pleistocene in age (Thomas quarry, Casablanca, Morocco; see Figure 4.10). Ssh: sandy ploughed layer. SNa: sandy material with Neolithic artefacts (wind-reworked pedological material). Sc/UP: sandy clay with Upper Paleolithic artefacts (reworked pedological material). Rwar/Mp: reworked argillic material with Middle Paleolithic artefacts. Ar: *in situ* well developed argillic horizon. Csd: zone of decalcification of calcarenite.

Iron crusts: These should be classified as follows: (a) monophased iron crusts (Figure 3.5), (b) polyphased and polycyclic iron crusts (Figure 3.6 and Figure 5.9) subdivided according to their chemical composition and their complexity expressed by the variety of sesquioxidic features and the number of accretional phases.

Mottled clays: (Figure 2.1 through 2.5, Figure 2.7, Figure 3.7) These are a deep soil horizon characterized by a bleached, commonly hard-setted matrix, free of faunal features, with ferruginous mottles randomly distributed. Various features of eluviation as well as of illuviation are observed under a polarizing microscope, the most common being intercalations of various sizes, sorting, and grain size distribution. They are or were affected by severe aquic conditions (US Soil Taxonomy) the equivalent of which in the WRB are gleyic properties. The abundance of ferruginous features increases from bottom to top. When ferruginization becomes dominant, this horizon becomes a plinthite. Mottled clays (Figure 2) either lie upon an isoalterite or are developed upon a sediment which usually originates from erosion of alterites or from any horizons of chemically mature soils. The transition to the overlying horizon is usually progressive. Mottled clay horizons can be subdivided according to their degree of bleaching, the intensity of eluviation, evidence of groundwater fluctuations through time, and the type of transition with isoalterites.

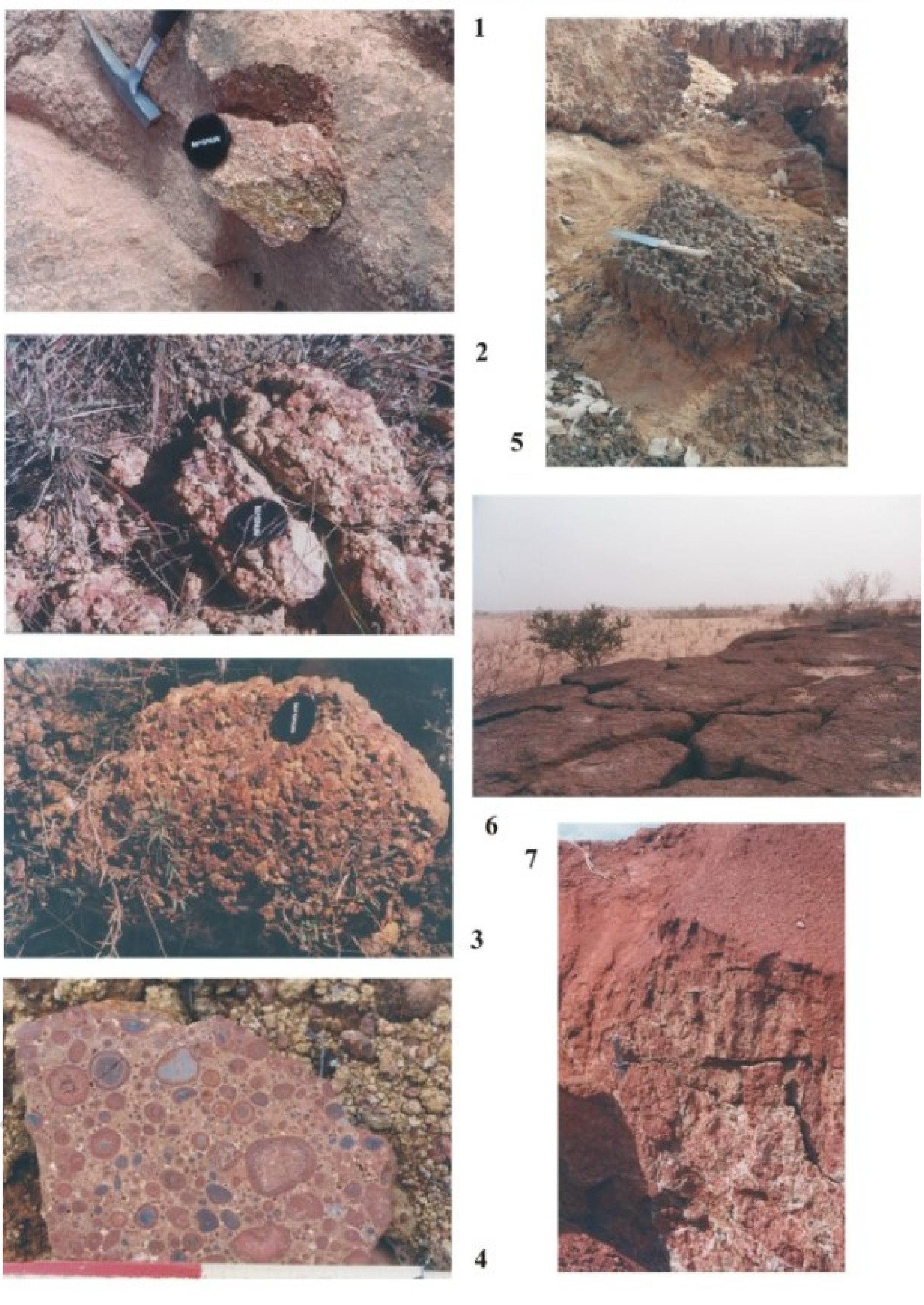

Figure 3. Tropical soils
(1) Isoalterite of a gneiss (area of Gotheye, north of Niamey, Niger). Whitish spots correspond to kaolinized feldspars. (2) Sample from a plinthic horizon collected on the top of a Cg horizon of a Plinthaquult (Youth Island, Cuba) merging with depth into mottled clays. Hardened, amiboid mottles consist of a bright red, irregular ferruginous nucleus which becomes paler (halo) towards the bleached matrix. (3) Sample from the surface eluvial nodular horizon which belongs to the same profile as Figure 3.2 (Youth Island, Cuba). Three types of nodules are recognizable in the field: (a) bright red

nodules in which the bright red nucleus is the same as in the Cg horizon (Figure 3.2), however the reddish halo is lost, (b) brown nodules whose external color results from the cortex (see Figure 5.8), (c) fully black nodules (see Figure 5.6). (4) Cemented nodular horizon (South Western Australia, Yilgarn craton, Jarrahdale). Various types of nuclei are recognizable with the naked eye as well as mono- and polyphased cortex (see monograph 6). (5) Monophased iron crust developed in late glacial dunes, probably during the Holocene optimum (area of Gotheye, north of Niamey, Niger). (6) Polyphased iron crust lying on a terrace above the sand dunes (area of Gotheye, north of Niamey, Niger). (7) Mottled clays lying under a typical red oxic horizon (Havana plain, Cuba).

Stone lines: These are common in chemically mature soils (Figure 2.9). Many polyphased iron crusts are in fact stone lines later cemented by iron oxides. Paleolithic artifacts in sub-Saharan Africa are usually included among stone lines.

The most characteristic and common diagnostic horizon in the upper compartment of chemically mature soils is the oxic horizon (US Soil Taxonomy; Figure 2.6 through 2.9, Figure 3.7 and Figure 4.8), the WRB equivalent being the ferralic horizon (from Latin *ferrum*, iron, and *alumen*, aluminum). Oxic horizons are characterized by (Figure 4.1 and Figure 5.10) a strong red or yellow very homogeneous soil matrix, a very strong microaggregation in the form of "pseudosand" and consequently a low bulk density, a clay fraction with a very low cation exchange capacity consisting of kaolinite with large amounts of iron, aluminum, manganese and titanium oxides (above 10%, rather frequently reaching 50%), a very low percentage of water-dispersible clay, and a very low percentage of weatherable minerals. Sesquioxides are present in the clay fraction in the form of crypto-hematite and goethite, abundant ferruginous (as well as manganiferous, titanium) microfragments, and ferruginous nodules in variable abundance, commonly absent. Microlaminated clay coatings and infillings can be present in oxic horizons which then appear compacted. These oxic horizons can be present in a large variety of soil profiles with a very variable thickness (Figure 2, Figure 3.7 and Figure 4.8). Usually they are in the few top meters of the soil profile, resting above the stone line when one is present, or alternatively the stone line can be intercalated within oxic material. Oxisols can be also very thick, some tenths of meters without any clearly defined horizon (Figure 2.6 and Figure 4.8). They can rest directly on an isoalterite, penetrating it in the form of fingers in the alterite, or more frequently on mottled clays (Figure 3.7) with a progressive transition. Nodular horizons and iron crusts can be included in oxic horizons.

Argillic horizons: These are characterized by containing a significantly higher percentage of phyllosilicate clay in a subsurface horizon than in the overlying soil material. They are frequent in chemically mature soils, although argillic horizons in general are not specific to the tropics, occurring from the Arctic to the tropics. One class, the Ultisols in the US Soil Taxonomy, is, however, specific to the tropics and subtropics. Ultisols have a base saturation (by sum of cations) of less than 35% at some depth in the profile. Argillic horizons are characterized by microlaminated clay coatings and infillings. However, these features can be present anywhere and in any chemically mature soils, the deepest already appearing in isoalterites.

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Micrographs

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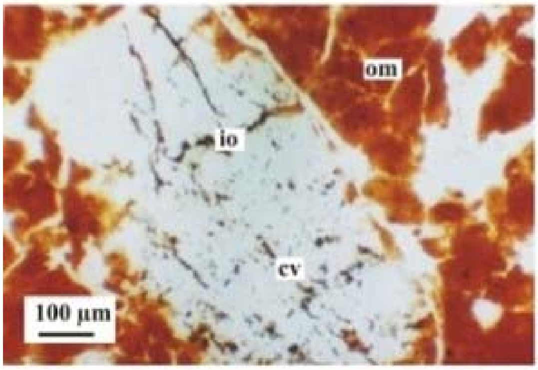

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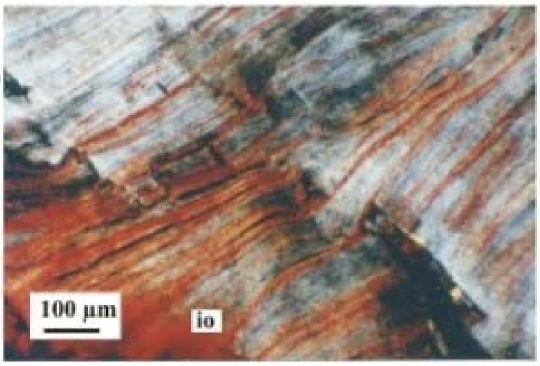

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Figure 4. Tropical soils (photographs 8–10, continuation of Figure 3) and their micromorphological study (micrographs 1–3)
(8) Thick, homogeneous, red oxic material (Northern Queensland, Australia, west of Cairns). (9) Weakly and progressively weathered granite (Brittany, Quintin hills, France). The slope of the hill is covered by laminated saprolite (in French, *arénes litées*)

while its core consists of fragmented, very little weathered granite (see Figure 2.10 for details). (10) Red Mediterranean complex soil profile lying on partly decalcified lithified sand dunes, Middle Pleistocene in age. On the karstified lithified dunes lies an argillic horizon, some thirty centimeters thick, characterized by common microlaminated clay coatings. On the argillic fabric are superimposed sparitic features. The argillic horizon is covered by a red, homogeneous material a few meters thick, in which two weakly developed stone lines are at present mixed with Middle and Upper Paleolithic tools. Neolithic artefacts occur in the upper paler layer (Thomas quarry, south of Casablanca, Morocco). (Micrograph 1) A corroded quartz grain embedded in an oxic matrix (Havana plain, Cuba). Corrosion voids are partly infilled by black sesquioxides. (Micrograph 2) A biotite completely transformed into kaolinite, characterized by its grey birefringence. Edges of biotite lamellae are coated by iron oxides inherited from an earlier stage of weathering (area of Gotheye, north of Niamey, Niger). (Micrograph 3) Opened lamellae of very weakly weathered biotite infilled by sparite (Calcareous crust on granite, Maresmas, north of Barcelona, Northeastern Spain).

Clay increase and abundance of clay coatings and infillings are not usually correlated. Frequently, different types of clay illuviation features are present in these profiles, commonly juxtaposed to one another. In thick Oxisols, compaction of some subhorizons is frequently due to clay coatings and infillings which bind the microaggregates. Spatially, Oxisols and Ultisols either form a mosaic, or the former are located on older geomorphic surfaces while the latter are on younger ones. Frequently, argillic horizons in the tropics do not contain any illuviation features or contain only a few which are insufficient to explain the clay increase. To avoid this uncertainty, the WRB soil classifiers proposed the argic diagnostic horizon in which the clay increase is not related to illuviation, while the US classifiers forged a new diagnostic horizon, the kandic (Figure 2.5), in which the clay increase is also supposed to be independent of illuviation, but meets the weatherable-minerals criterion for an oxic horizon, contains 40% or more clay and no "pseudosands".

The WRB also distinguishes a nitic diagnostic horizon (from Latin *nitidus*, shiny), only present in the tropics, which is in fact a type of argic. The main feature of nitic horizons is a moderately polyedric or nitty structure with many shiny aggregate faces, which cannot or can only partially be attributed to clay illuviation.

Surface horizons of chemically mature soils exhibit rather low variability. The following are proposed by the US Soil Taxonomy and the WRB:

- The albic horizon (from Latin *albus* white; Figure 2.3) is an eluvial in which the color is determined by uncoated sand and silt grains, the clayey mass being almost absent. In the tropics, albic matrices and horizons result from surface water and groundwater moving with high energy through the soil. For example, the matrix of nodular horizons can be albic, and some mottled clays merge locally into albic material. Sandy sediments, several meters thick as in Amazonia, that are affected by groundwater correspond to albic characters.
- The ochric epipedon (US Soil Taxonomy) or horizon (WRB) (from Greek *ochros*, pale) is light colored and has a low organic carbon content; it can be

massive and hard when dry. This epipedon is not specific to the tropics. It occurs there mainly overlying argillic horizons.

- The umbric epipedon (US Soil Taxonomy) or horizon (WRB) (from Latin *umbra*, shade; Figure 2.4 and 2.5) is thick, dark-colored, base desaturated, rich in organic carbon, massive, but rather friable. In the tropics, umbric epipedon occurs mainly as Ultisol and Andosol surface horizons.

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Biographical Sketch

Nicolas Fedoroff, an associate professor at the Agricultural University of Paris (France), teaches soil genesis and soil classification in the department of Agronomy and Environment. He is also delivering there a course on tropical soils, genesis, and management; coordinating Earth Sciences; and delivering a course on soils and paleosols at *Diplôme d'Etudes Approfondies* (equivalent to a PhD course) on Environmental Archaeology of University Paris. He has been an invited professor at various universities and research institutes, such as Université Laval (Sainte Foy, Québec) and Université du Québec à Montréal (Canada), Instituto Geographico Agustin Codazzi (Bogota, Colombia), Post-grade University of Agriculture of Montecillos (Mexico), Moscou State University (Russia), and the Agricultural University of Tunisia. He was made Doctor Honoris Causa of the Polytechnic University of Barcelona.

In the late 1960s, he introduced Soil Micromorphology in France and has since developed it. In 1985, he organized the Seventh International Working Meeting on Soil Micromorphology in Paris and later he was elected president of the Soil Micromorphology subcommission of the International Soil Science Society. He is one of the authors of the basic textbook, *Handbook for Soil Thin Section Description* and he has co-edited the Proceedings of the Paris meeting. Almost all of his papers on soil genesis and paleosols have a micromorphological support.

Nicolas Fedoroff has trained and supervised more than 30 PhD students from all over the world. They all came to his lab in order to be trained in Soil Micromorphology and for applying microscopic techniques to a wide variety of themes.

The relationships existing between aeolian dust deposition, sand dune accretion, soil forming processes, and erosional phases is one these themes. Investigations were conducted on loess in the Paris basin, on the Loess Plateau of China, on the Colombia Plateau (Washington, USA) and on stabilized dunes in the Sahel (Niger). Presently, he is continuing these investigations on the Dogon Plateau (Mali).

The genesis of Lateritic soils and Oxisols is another theme. On Youth Island, a small island south of the Cuba mainland, a toposequence only a few kilometers in length was thoroughly investigated. It consists of incipient soils lying on an almost unweathered bedrock to well developed Laterites. Later, these Youth Island soils were compared with the Oxisols of the Havana plain. Intermediately developed Lateritic soils were also studied on the coastal plain of southern Mexico. Relict, highly developed, Lateritic soils were also tackled in Western Africa (Mai and Niger). Nicolas Fedoroff has also visited Lateritic soils and Oxisols in Australia (Queensland and South Western Australia) as well as in northeastern Argentina.

Pedologists usually do not take into account the various processes of soil reworking. Complex soil materials resulting of aeolian volcanic deposits and slope horizon slides have been investigated in intramountainous basins of Andes in Colombia and of Central Mexico (tepetates).

Two theses on sustainable agriculture were also supervised by Nicolas Fedoroff, one in tropical Mexico (erosion and soil ecosystem conservation), the other on human-induced alkalinization in the inner delta of Niger (Mali).

He has also been involved in international research programs such as Archaeomedes, funded by the European Union. The soil sustainability of a small basin, the Vera basin (southeastern Spain) since the beginning of agriculture (Neolithic) was investigated by correlating data on civilization collapses and evolution of soils through time.

Presently, Nicolas Fedoroff is interested by identifying in soils and paleosols features and fabrics which could have been formed during abrupt climatic events such as the Younger Dryas or Henrich events.