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AMAZON LANDFORMS AND SOILS IN RELATION TO SPECIES DIVERSITY

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Proceedings of a Workshop to determine priority areas for conservation in Amazonia, 10-20 January 1990, Manaus, Brazil ("Workshop 90")

INTERNATIONAL SOIL REFERENCE AND INFORMATION CENTRE

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W.G. Sombroek[1]

1. INTRODUCTION

The international workshop to define priority areas for conservation in Amazonia on the basis of a biogeography map of the region recognised the need to augment the aggregated information on flora and fauna with geographically-oriented studies on the Amazon climates, geomorphology/landforms, soils, hydrology/limnology, and human population patterns. The reasons were threefold:
- The characteristics and history of the physical and human resources may explain some of the observed spatial differences in the various aspects of floral and faunal species diversity;
- The geography of these resources may help in establishing boundaries of biogeographic units in areas where the number of observations as flora and fauna is scarce or skewed;
- The ecological fragility of the physical resources themselves may constitute a reason on its own to include certain areas in the map on priority areas for conservation.

The below text deals with the aspects of landforms and soils. It is accompanied by a schematic cross section of the region showing the relationships landform, vegetation, and soils as well as a small scale map on landforms and soils (a draft map at the same scale as the biogeography map is available with the author).

2. LANDFORMS AND THEIR STABILITY

Very schematically, the main landforms of the Amazon region are as follows (from high to low):

a) Flat to gently undulating high-level (> 500 m alt.) table lands, mainly on weathering-resistant arkonic sandstones (Proterozoic Roraima formation and others), concentrated in the water divide regions of the main tributaries of the Amazon. Examples of these **sandstone table lands** are the "tepuis" of Venezuela, the "chapadas" of Brazil and the "mesas" of the Colombian part. It is assumed that these table lands are geomorphologically stable since Cretaceous times, if not earlier, although the process of upheaval may have lasted until the Pleistocene (Kubitzki, 1989).

b) Steeplands on weathering-resistant parts of the crystalline shields. These are the **inselberg-complexes** of the frontier zone Guyana-Brazil-Venezuela-Colombia and the mountainous lands of the Brazilian shield and associated colluvia and alluvia. Reshaping of the land is likely to have taken place all through the Pleistocene.

c) Steeplands, interhill valleys and colluvial fans of the Andean fringe, on a variety of geologic materials: the **selva alta areas** of Colombia, Ecuador, Peru and Bolivia, with dissection still going on.

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d) Rolling to hilly dissected lands - rounded hills with convex slopes of the crystalline-basement rocks, and adjoining outcropping Paleozoic-Mesozoic sedimentary rocks - where weathering resistance is smaller. They occupy the main part of the Guyana and Brazilian shield areas and can be denominated as **Shield uplands**. Dissection has presumably been active as recent as in the Late Pleistocene. In places the terrain may be only gently undulating, constituting remnants of early planation surfaces (Sul-americana and Velhas levels of King, 1957).

e) Flat, intermediate-level plateaus (100-300 m alt.) of the eastern part of the sedimentary basin, with a cover of kaolinitic sedimentary clays. This is the **Amazon planalto** with the so-called Belterra clay, of supposedly lacustrine origin. These plateau lands, often with steep scarps, are most prevalent between the lower reaches of the Tapajós and Xingú rivers (see maplet in Klammer, 1984), as well as in the upper reaches of the Gurupú catchment (Sombroek, 1966, p. 18-26 and appendices 1, 4 and 5). The plateau remnants have not been dissected in the Pleistocene epoch.

f) Gently undulating, relatively high lying land with concave slopes, on either crystalline basement or Cretaceous-Tertiary deposits. These can be denominated **suspended valleys** and are thought to be prevalent in the southern fringe of the region (headwaters of the Xingu and the Tapajós rivers). They can however also be observed locally in the central basin, for instance in the upper reaches of the Curuá-una river southeast of Santarém (Klammer, 1984, p. 65-66), the upper reaches of the Capim river south of Belém, and in some sections of the sedimentary area between Manaus and Itacoatiara. In the latter cases it apparently often concerns an Early Pleistocene reworking of Belterra clay by erosion and short-distance deposition without any dissection in later parts of the Pleistocene epoch.

The savannah areas around Boa Vista (Roraima State of Brazil) may constitute a variant of these Early Pleistocene suspended valleys. At that time the area has apparently been in direct contact with the Atlantic Ocean through the present-day Essequibo river valley of Guyana, forming a small inland sea or bay.

g) Alternation of flat and undulating land, the latter often with convex slopes, of the Pleistocene glacio-eustatic terrace levels in the eastern part of the basin. These stepped depositional plains (cf. Fig. 1, copied from Klammer, 1984), or **eastern sedimentary uplands**, occur on fluviatile sediments derived from Cretaceous and Tertiary pre-weathered materials from the crystalline shields. Dissection has taken place presumably throughout the Pleistocene due to interfluvial-pluvial alternations and base level oscillations.

h) Undulating to rolling land, often with convex slopes, of the western part of the basin, on sediments derived from the Andean cordillera by fluviatile and sometimes volcano-aeolic deposition. Also these **western sedimentary uplands** have undergone dissection throughout the Pleistocene.

i) Flat to gently undulating, relatively low-lying lands with a sandy surface over basement rocks. Such denudational **sandy plains** are prevalent in the Rio Negro and middle Rio Branco areas. Presumably these plains have been remodelled in the Late Pleistocene, after capture of some of the former tributaries of the Orinoco and Essequibo by the Amazon river system. This capture would have resulted in a sudden huge increase in river discharge of the Amazon tributaries accompanied by a selective clearing away of ⌊any Early Pleistocene or Tertiary-Cretaceous sedimentary cover. Such sandy plains also occur in a band between the crystalline uplands and the coastal sediments in the Guyanas; their sedimentary source may have been the Roraima sandstone formations.

j) Flat to gently undulating, relatively low-lying land with loamy sediments, prevalent in the lower Juruá-Purús-Madeira river areas southwest of Manaus. These are apparently plains with Late Pleistocene or Early Holocene sediments deposited by the rivers originating in the southern part of the Andean Cordillera. The surface of these **loamy plains** still show relic features of meandering rivers as demonstrated by Klammer (1984) and Irion (1976 et seq.) The surficial deposits in the

 ⌊ clayey parts of

lower Juruá-Madeira area may date from the postulated Late Pleistocene or Early Holocene disengorgement of an antecedent of Lake Titicaca in the Altiplano area of Bolivia and Peru, which would have resulted in a huge temporary interior lake according to Campbell et al. (1985) and Frailey et al. (1988). Regional flooding in the Ecuadorian part of the western Amazon would have taken place as recent as 1300-800 BP (Colinvaux, 1987).

Variants of such Late Pleistocene loamy plains are found in the Beni area of northeastern Bolivia, in the lower Gurupí-Maracassumé area of northern Maranhão (see map of Camargo et al., 1981), and on the west bank of the lower Tocantins river and the erstwhile continuation thereof on the southeastern fringe of Marajó island.

k) Flat lands and inland waters alongside the major rivers, constituting Holocene floodplain generations. In some parts the floodplains are accompanied by extensive marshy bottomland areas, such as around the middle reaches of the Marañon river in Peru (the Pastaza basin). Details of these **floodplain-bottomland complexes** are given by Klammer (1984, p. 68) and Rasanen et al. (1987).

In summary, only the sandstone table lands, the Amazon planalto and the suspended valleys are likely to have been stable in their physiography - and hence had an uninterrupted soil development - since Early Pleistocene times.

3. SOILS AND [THE STRUCTURE OF] THE VEGETATIVE COVER

The below gives a non-technical description of the main soils of the region and the structure of their vegetative cover, following the subdivision of the landforms as given above. Only the FAO/Unesco terminology for soil classification (FAO, 1974; 1988) is given. For the naming in other systems such as the US "Soil Taxonomy" one and the Brazilian scheme see the review of Sombroek (1984). The latter also gives more details of the chemico-physical characteristics and properties of the soils than described in the present text, with an assessment of the agricultural potential of the soils, and references of the pertinent soil literature. For soil-vegetation relationships see also Brown (1987) for the Brazilian part, and Huber (1982) for the Venezuelan part.

a) The soils of the **sandstone table lands** are predominantly shallow, sandy and podzolised (albic Arenosols; Podzols; Lithosols). They support at present a savannah or low-forest vegetation ("campina rupestre"). Scarp-like edges have often stony soils, with more vegetative cover than the flat tops.

b) The **inselberg complexes** have a catenary sequence in soil conditions. Bare rock outcrops and very shallow soils (Lithosols) of the inselbergs and other mountainous parts alternate with deep, often sandy soils (albic and ferralic Arenosols) on the colluvia at the feet of the inselbergs, and yellowish to reddish loamy soils on the bands of well-drained uplands and alluvia in-between (xanthic Ferralsols and Acrisols). The inselbergs have a shrubby vegetation, the footslopes a mosaic of forest and savannah, while the uplands and alluvia support high forest.

c) The steepland-and-valley complexes of the **Selva Alta** area have an extremely strong variation in soil conditions, as a consequence of the prevalent short-distance variation in lithology, slope position and meso-climatic conditions (the area around Tarapoto in Peru has even a subhumid climate, with a long dry season). A schematic subdivision is as follows: Rock outcrops or shallow and stony soils (Lithosols; shallow phases of Cambisols) are found on steep upper slopes; they often carry low forest only. Well-drained, deep, reddish, loamy to clayey and in part stony soils with variable ion exchange capacity, base saturation, and mineral reserve (Ferralsols, Acrisols, Luvisols, Nitosols) are found on the middle slopes, and they support high forest. Bands of Pleistocene terrace lands may have a strong internal differentiation in texture and acidity ("duplex" soils or Planosols), on which a shrubby vegetation prevails (a high terrace in the Bella Vista area of the upper Huallaga river even showed a cobble layer in the subsoil, as proof of Pleistocene interfluvial conditions). Low upland and bottomland parts can have base rich cracking clay soils (Vertisols) with a scrub vegetation, while floodplain stretches have base-rich silty soils (Fluvisols) with a cover of high forest.

d) The **shield uplands** have often also a short-distance variation in soil conditions. Areas with steep slopes or resistant rocks have rather shallow soils, but with a substantial content of weatherable minerals (Cambisols). Most of the soils are however deep to rather deep, well-drained, reddish, loamy to clayey and acid. Part of them have a degree of textural differentiation with relatively compact subsoils, a degree of weatherable minerals and varying clay-mineral activity (ferric or orthic Acrisols); these soils sustain often an open-canopy forest with a dense undergrowth. Others are more homogeneous in their vertical build-up, with little or no weatherable mineral reserve and an inactive clay mineralogy (orthic and rhodic Ferralsols); these carry predominantly closed-canopy high forest.

Areas with a substratum of dioritic crystalline rocks, basalts, or ferro-magnesian rich Paleozoic-Mesozoic Sedimentary rocks may have dusky red, deep and clayey soils of good structure, with a high percentage of active clay-sized ironoxides (Nitisols). These so-called "terra roxa estruturada" soils of the Brazilian soil classification system occur along parts of the Transamazon highway; in the upper Xingu area, and in places in Rondonia (Camargo, 1981). They support a luxuriant forest cover, but are also much sought after for permanent settlement (cocoa growing!) because of their favourable physical and chemical properties.

e) In contrast to the above, the **Amazon planalto** has a monotonous cover of very deep, very clayey, acid, yellowish soils of very low physico-chemical activity and no mineral reserve (xanthic to acric Ferralsols). Most of them are deeply porous and friable and then support high, closed-canopy forest. Central parts of planalto stretches, far away from the scarps, can however have compact subsoils, in these cases the vegetative cover can be a liana rich open-canopy forest, or even pure liana forest or "cipoal" (Sombroek, 1966, p. 194-196). The latter vegetation type predominates on the left bank of the lower Xingú and may be the enduring result of past indian occupation (Balée and Campbell, 1989).

f) The areas of the **suspended valleys** with their gentle concave slopes have predominantly very deep, loamy to clayey and sometimes concretionary, acid, yellowish to reddish soils of low to very low physico-chemical activity (xanthic or orthic Ferralsols), supporting high forest of large timber volume unless climatic conditions are marginal such as in the upper reaches of the Xingú and Tapajós catchments [if indeed these can be denominated suspended valleys].

The Boa Vista variant of suspended valleys have however predominantly a savannah cover because the soils overthere have a strong textural differentiation (sandy topsoils over compact, clayey subsoils, and/or occurrence of massive ironstone layers (Arenosols, Planosols, Plinthosols, ironstone Lithosols). It is hypothesized that this divergent soil development is due to a brackish-water lagoonal depositional character of the parent materials, of Early Pleistocene age [c.f. the Late Pleistocene soil-landform pattern in the Lagoa dos Patos/Lagos Merim area south of Porto Alegre, Brazil].

g) The **eastern sedimentary uplands** have well-drained, very deep, acid, yellowish soils with textures that laterally vary from loamy sand to light clay with low percentages of silt, but are vertically homogeneous. The soils have no weatherable mineral reserve and are physico-chemically very inactive, especially on the flat parts of the upper terraces (Sombroek, 1966, p. 167-171) but they are porous and friable throughout (xanthic Ferralsols; some ferralic Arenosols). They support a closed-canopy high forest of large to fair timber volume. In part, the soils contain ironstone concretionary layers, but his has normally no detrimental effect on the forest structure. Very sandy patches on the higher uplands may have a white-sand soil profile, but then without any water stagnating subsoil layer (ortstein, see below). Such patches of albic Arenosols, or "giant podzols" also support closed-canopy forest, be it of low timber volume; disturbance by present or past occupation however prevents forest regrowth.

h) The soil condition on the **western sedimentary uplands** contrast distinctly with those of eastern ones described above, because the sediments concerned were less pre-weathered at the time of their deposition. The soils are predominantly deep, well drained, yellowish red and acid. They have however a clay mineral assemblage that results in higher ion-exchange capacities. The over-all textures vary, but the silt content is relatively high, and there is some reserve of weatherable minerals. Many of these soils show a substantial textural differentiation and the deeper subsoils may show reddish mottling ("pseudo-plinthite", i.e. not hardening upon exposure). These ferric or orthic Acrisols have a forest cover, often with a rather open canopy but with valuable species such as *Bertholetia and Hevea spp.*

In the southwestern part viz. Acre state of Brazil and the adjoining part of Peru variants occur with high base status (ferric Luvisols) and the forest structure may then be determined by the occurrence of bamboo (*Bambusa superba*), either scattered or in dense stands.

Some of the soils of the western sedimentary uplands show little or no textural differentiation. They may have a high base saturation (eutric Cambisols, eutric Nitisols) or be acid (ferralic Cambisols); in both cases high and closed-canopy forest prevails.

i) The **sandy plains** of the Rio Negro - middle Rio Branco areas and of the Guyanas have continuously imperfectly drained soils. They are characterized by a subsurface horizon that consists of light grey to white sand or loamy sand of single-grain structure. This is underlain by a subsoil, at strongly varying depth, that is homogeneously or banded dark brown to black, with a texture that is only little heavier than the overlying layer but with a firm consistence or even cementation - causing low water permeability and root penetrability. This hardpan, or "ortstein", may be continuous or show a very irregular lateral pattern to the extent that in places it may be completely absent. Throughout the profile the soil is very acid and there is no reserve of weatherable minerals whatsoever (gleyic Podzols, or albic Arenosols if the white layer is thicker than 200 cm). The natural vegetation on such soils is either a savannah with common bare sand patches ("campina"; "bana") or a closed-canopy but low forest (Amazon "caatinga"). Clearing of this vegetation would result in permanent exposure of the white sandy soil, which is the reason why the areas with these fragile or "ecotonal" soil conditions have been delineated on the 1:5 M conservation priority map.

j) The **loamy plains**, as concentrated in the region southwest of Manaus have intermittently imperfectly drained soils of low structural stability. A relatively light textured topsoil overlies a loamy to clayey subsoil that has a compact consistence with prominent, coarse and abundant red mottles in a light grey matrix. The centres of these mottles are usually hardened and at the transition zone between topsoil and subsoil a thin layer of discrete iron-magnesium concretions may occur. The mottles, called "plinthite" in modern soil science, become irreversibly hardened to slag-like material upon exposure to the open air for several seasons: laterite concretions or "ironstone".

The base saturation in the soil is low throughout, and the physico-chemical activity of the clay mineral is low to very low. These soils are the "groundwater laterites" of early pedological literature, now denominated plinthic Acrisols (FAO, 1974) or Plinthosols (FAO, 1988). Their vegetation consists either of a poor and low type of forest, often with a predominance of palms, or of a shrubby or open grass savannah ("campo"). Clearing of this vegetation would result in irreversible hardening of some of the plinthitic subsoil, which may be aggravated upon erosion of the unstable topsoil. For this reason the area with plinthitic loamy plains has been delineated on the 1:5 M conservation priority map.

k) The **floodplain and bottomland complexes** along the major rivers have a strong short-distance variation in soil conditions. Although a broad grouping as "alluvial soils" can be made because sedimentary stratification still overrides any pedogenetic profile development, the soils vary much in their texture, their internal drainage conditions, their organic matter content, acidity, and clay mineralogy - depending on the local flooding conditions, the source of the sediments and the time elapsed since their (re-)deposition (Fluvisols, Gleysols, gleyic Acrisols, Vertisols, Histosols).

In general, the floodplain and bottomland complexes with sediments from the Andean cordillera ("varzeas" or "barriales" of "agua branca" rivers) are base-rich and have a clay mineralogy of high physico-chemical activity. They support a luxuriant forest cover, often with many palm species, or rich natural grasslands where the hydrological regime impedes tree growth. In the Pastaza bottomlands of Peru palm forests predominate.

The rivers originating in the crystalline shields or in the sedimentary basin itself carry little or no sediments and may contain high percentages of humic acids ("varzeas" and "igapos" of "agua limpa/azul" or "agua preta" rivers). The resulting soils are predominantly acid, with clay minerals of lower activity, and the forest cover is less luxuriant.

The lowlands along the Atlantic coast have soils that are, or have been, subject to the influence of brackish or saltwater (Solonchak, thionic Fluvisols, Gleysols). Their natural vegetation is mangrove forest, or grassland like on the central and northern parts of Marajó-island.

4. SPECIES DIVERSITY

The above overview of the major landforms and soils of the Amazon region, in a historical perspective, allows for some observations on the likely distribution of the three aspects of floral and faunal species diversity. These are: species richness or alpha-diversity; species endemism, or beta-diversity; and inter- and intra-species genetic variation, speciation or gamma diversity.

4.1 **Species richness**, or the number of species per standard size of land, for instance per km^2, is bound to be highest in ares with a short-distance strong variation in habitat, i.e. soil-, hydrological and micro-climatic conditions. These situations can be found in areas where geomorpho-genetic processes have been active in several episodes of the Pleistocene epoch, as the result of periodic changes in pluviosity coinciding with glaciations in the higher latitudes and altitudes and concurrent lowering in base-level of the hydrographic catchments. Especially where such geomorphologic activity resulted in exposure of fresh rock of short-distance contrasting lithology and mineralogy, the new pedogenesis resulted in soils of different depth, drainage condition, nutrient content, clay mineral assemblage and trace elements occurrence - allowing for many floral and faunal species to find their required habitat for reproduction and seed dispersal.

From the descriptions in sections 2 and 3 and the schematic cross section it may be obvious that such conditions can be found most pronouncedly in the steepland-and-valley complexes of the Selva Alta area, on the shield uplands with their convex slopes, and on the inselberg complexes. To a lesser degree it applies to the eastern and western sedimentary uplands, because of their relative spatial monotony in soil parent materials. A special case is formed by the floodplain-and-bottomland complexes of the agua branca rivers originating in the Andean cordillera: the fluvial dynamics during the Late Pleistocene and the Holocene is causing rapid vegetational successions due to changing sedimentological and hydrological habitats, as demonstrated by Salo and Räsänen (1988).

4.2 **Species endemism**, or disjunct distribution of species in a macro-spatial context, is likely to be linked to extreme climatic or edaphic conditions, where such species would have a relative advantage in the competition with other species.

Certain species would thrive in areas with a strong dry season, such as large parts of eastern Amazonia and the southern and northern fringes of the shield areas. Other species find their niche in conditions of year-long excessive rainfall such as the upper Colombian part of the Amazon region - cf. details in Salati's contribution(?). Extreme hydrological conditions are found in the various flood plains and bottomlands; their influence on species endemism is discussed in detail by Junk(?).

Amongst extreme soil conditions first of all mention should be made of the white-sand soils of the sandy plains, the table lands and part of the inselberg complexes. The specific floral species composition of their "campina" and "caatinga Amazonica" vegetative cover is well documented (Ducke and Black, 1953; Murça-Pires, 1978; Jordan, 1989; and others). Another example are the marshy and peaty Paztaza bottomlands of Peru, where palm species predominate.

Also the forest on the parts with Nitisols on the crystalline shield are reported to have an aberrant tree species composition (more soft wooded species; Ducke and Black, 1953) and the same may apply to the nutrient-rich soils with a surmised or established influence of volcanic ash of parts of Acre, the adjoining part of Peru and of the Ecuadorian part of the region.

The prized timber species Cedro (*Cedrela odorata*) and Mahogany (*Swietenia macrophylla*) are found predominantly in climatically marginal areas at the southern and southwestern fringe of the forest region; for mahogany a special study was carried out by the FAO/Unesco forest inventory team in 1961 in the lower Araquaia area. The species was found to be concentrated on well developed hydromorphic soils with a high physico-chemical activity ("hydromorphic grey podzolic soils" or gleyic Luvisols, Sombroek, 1966, p. 203-208; and maplets).

[Even in the areas with a seemingly monotonous cover of well drained acid yellowish soils (xanthic or orthic Ferralsols) of the eastern sedimentary uplands and the associated suspended valleys there are phytogeographic differences. This applies for instance (Sombroek, 1966, p. 198-203) to the occurrence of Angelim pedra (*Hymenolobium excelcum*) which is found preferably on non-compacted soils on the Belterra clay, either in its original position at the Amazon planalto or remodelled at suspended valley levels.

Pau Amarelo (*Euxylophora paraensis*) is found on soils with a substratum of plinthitic and concretionary material of the Ipixuna type (which immediately overlies bauxitic material such as in the Paragominas area).]

4.3 **Speciation**, or the evolution of new species and the development of a large intra-species genetic variation, is to be found in areas where landforms and soils have been stable over a long period of time and past climatological conditions have not been much different from today. Because of the latter condition areas of speciation are supposed to coincide with refuge areas or "refugios": parts of the Amazon region where a forest coverage prevailed throughout the Late Tertiary and the Pleistocene. Such areas would serve as a refuge for floral and faunal species of a forest environment in times of aridity and as a source of expansion in times of renewed pluviosity. A maplet on the Amazon areas where tropical humid forest probably persisted in the last ice age (Wisconsin-Würm) is given by Brown (1987). The concept of refugia is much debated these days (Whitmore, Prance, Gentry, Colimaux, and others; see elsewhere in this volume; maplets of Keith Brown(?)), but from the geomorphologic-soils point of view sites of large speciation are likely to be found on the sandstone table lands, on the Amazon planalto stretches and in the areas with suspended valleys. The rather extreme soil conditions of these geomorphic units, especially on the table lands and the planalto (sandiness, shallowness, compactness, very low clay mineral activity, strong acidity, and/or lack of weatherable minerals) would however be a detrimental factor for the survival of a number of species in-loco, especially during times of droughty conditions in the region as a whole. It is postulated that at the advance of such times the forest species gradually moved to the edges and scarps of the table lands and plateaus. The occurrence of less-extreme soils and the likelihood of more orographic rainfall at the windward sides of these scarps would then allow for survival, with a subsequent creeping back of the species to the flat tops at improvement of the over-all pluviosity of the region. A case in point may be the relatively high and steep scarps (100-200 m) of the Planalto stretches of the upper Gurupi catchment in eastern Pará state of Brazil, which is one of the suggested refugia.

In the case of the suspended valleys, especially those at the southern fringe of the presentday Amazon forest region, the forest vegetation would have temporarily withdrawn to narrow fringes of gallery forest on the lower parts of the stable concave-slope landscape, where supply of groundwater would recompense for a seasonal shortage of rainfall.

Detailed multidisciplinary studies are needed to establish geographic relationships between speciation, past climatic conditions, stability of landforms and uninterrupted soil development during successive geologic epochs, before more definite conclusions can be drawn on the validity of the refugia concept.

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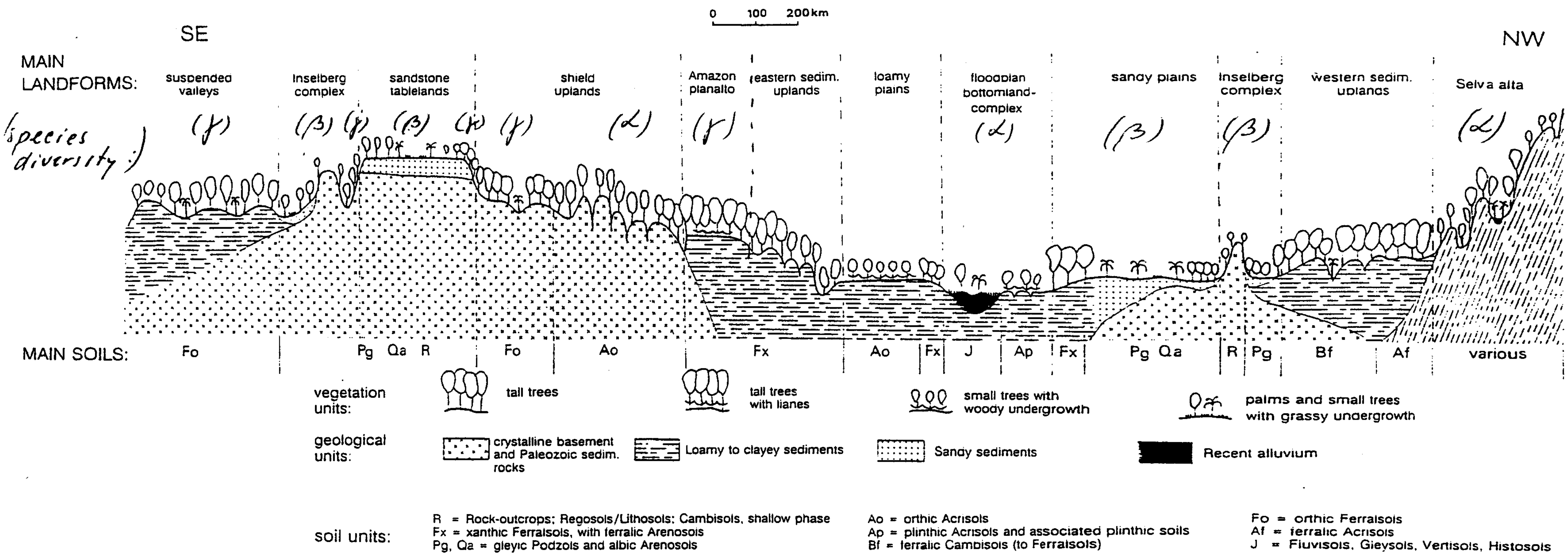


fig 1. Schematic cross-section of the Amazon region, showing the relationship lithology - landforms - soils - vegetative structure (-species diversity)

to be included or deleted??

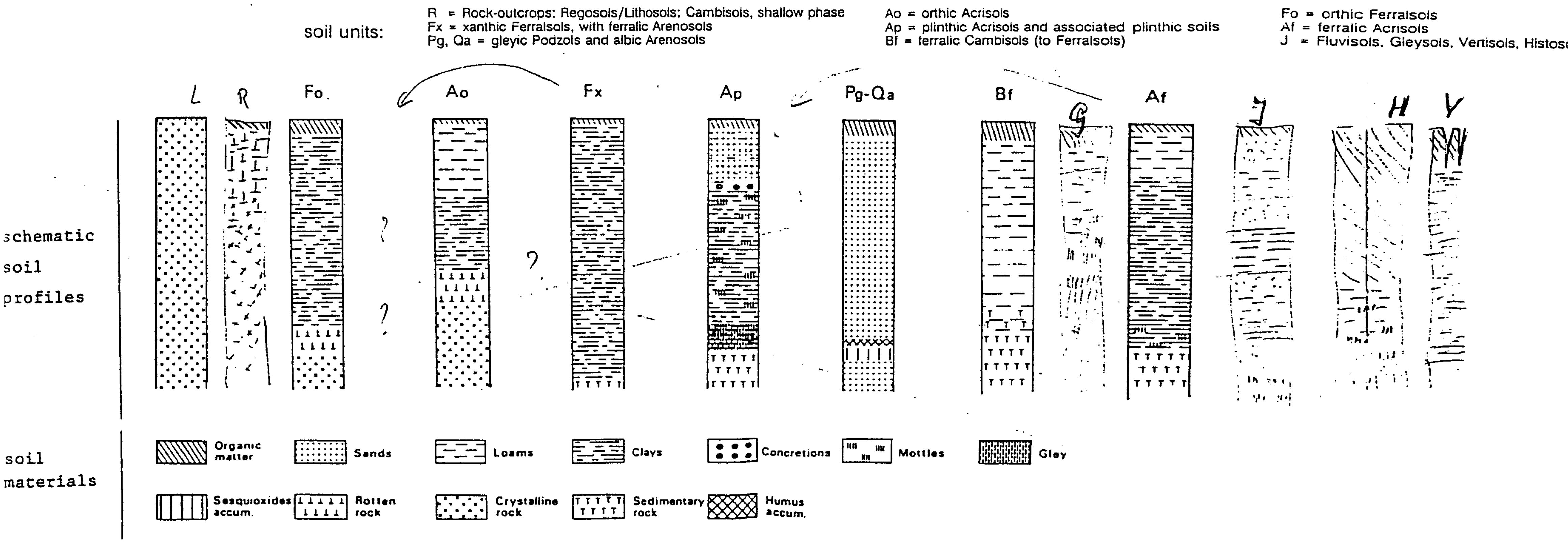
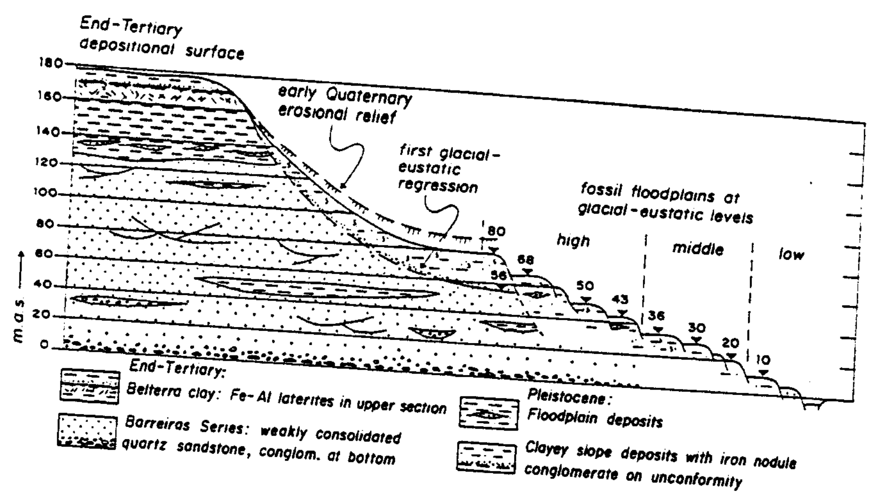


Fig 1a Main soil profiles of the Amazon region

to be added to fig 1. or to be deleted??



~~Fig. 11~~ Late Pliocene and Quaternary depositional and erosion events in alluvial Amazonia, and the corresponding relief generations. In the centre of the basin only the low and middle flood plains are preserved. (Klammer 1984) fig... Sketchmap of the main landforms of the Amazon region.

T = Sandstone table lands

I = inselberg/mountainous land complexes

S = steeplands and valleys of the Selva Alta

Uc = crystalline shield uplands

A = Amazon planalto

V = suspended valleys

(Vr = suspended valleys of Roraima)

Ue = eastern sedimentary uplands

Ua = western sedimentary uplands

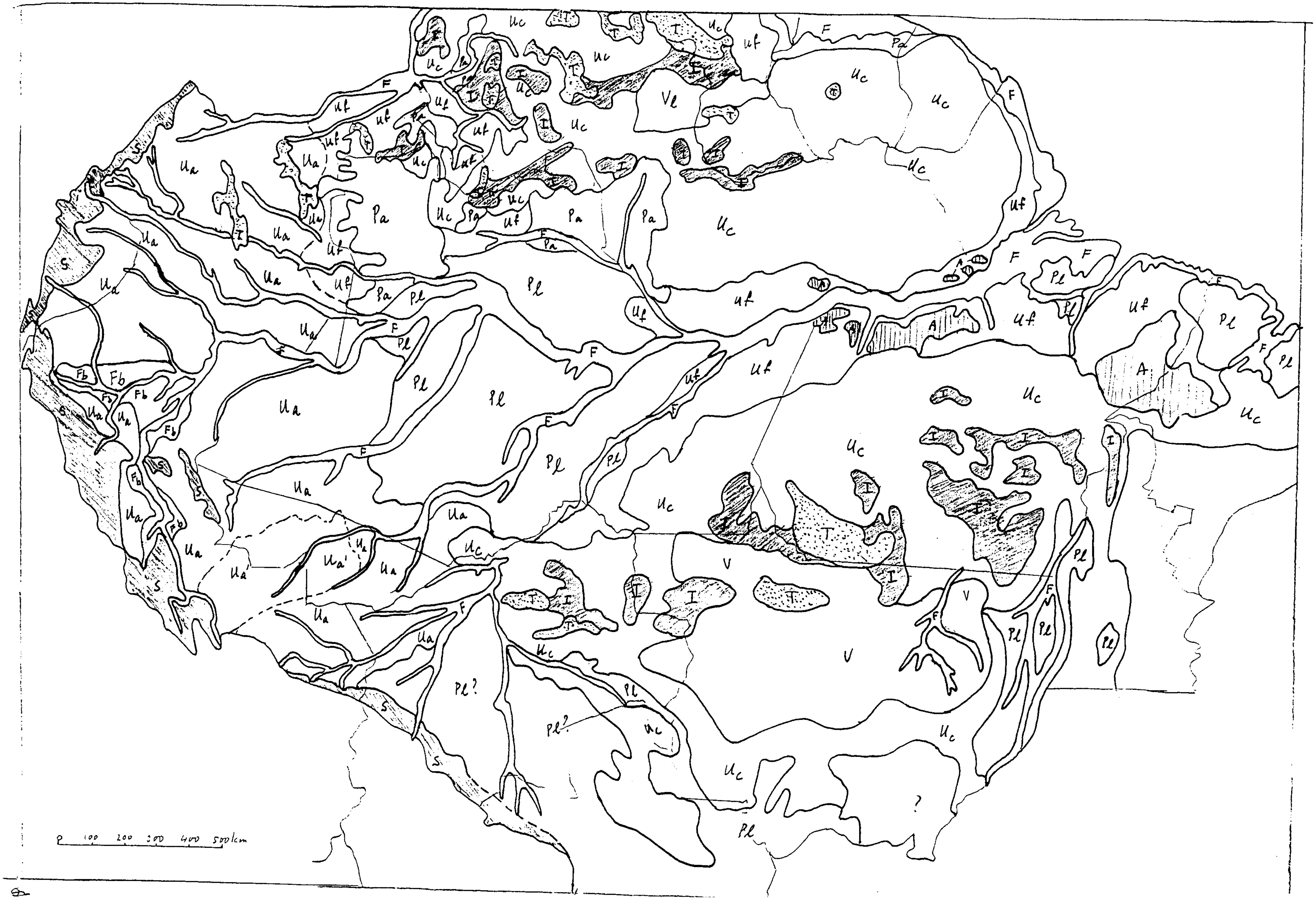
(Ua' = ash-enriched?)

Pa = sandy plains

Pl = loamy plains

F = floodplain-bottomland complexes

(Fb = extensive bottomlands)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