According to the Wola of the Southern Highlands of Papua New Guinea earthworms are not harmless creatures that merely croak, as the Kalam of the Western Highlands believe (Bulmer 1968), they are harmful animals that bite. And their bite, while not felt like that of a dog, causes aching pains. It is not unusual to see a woman nursing a painful and sometimes swollen knee, and attributing it to a bite received from a worm while kneeling in a garden heaping up sweet potato mounds, work in which women commonly engage. They are adamant that it is a nip from an earthworm that causes their discomfort, and a European holding a large worm in his hand for many minutes with no discomfiture nor pain does nothing to disprove their belief – this merely proves what they already know, that Europeans have power to protect themselves from ailments that afflict them (like malaria), and leads to demands for some of the appropriate medicine to alleviate their worm-induced suffering (the attention that Western medicine gives to intestinal worms, distributing medicine to purge them, reinforces this attitude).

Although I have periodically racked my brains ever since learning about the Wola fear of earthworms for some ‘explanation’ of it, symbolic or otherwise, I confess that I have drawn a blank. The Wola themselves, who call earthworms gogay (Amyntas spp, Metapheretima spp. among others), point to their strange appearance: not only no legs, hair or feathers, but no eyes, nose or even mouth, and yet they bite, but mouthless without being felt, and they apparently eat nothing except soil. The similarity with snakes might be taken as a possible clue to their fear of the earthworm, for the Wola believe that their ancestors’ spirits, which can cause them sickness and death, manifest themselves as snakes. Yet they kill, cook and eat large pythons (Liasis spp.), but believe that if a worm merely crawls over some food the individual eating it will fall ill. Nor is it that living in the earth, a dark subterranean existence, necessarily makes them fearsome, for there are several other soil dwelling animals that are not feared, some of which are edible; they include the bombock mole-cricket (Gryllotalpa sp.), the mol cricket (Gymnogryllus angustus), kaewuwmw cricket (Gryllus bimaculatus), kaengap stagbeetle (Dorcinae subfamily), wathul barking spiders (Selanocosmia sp.), domasil ants (various members of Formicidae family), and nolai cicada nymphs (Pomponia sp.).

The Wola, like most of us, do not think overly on matters that frighten them and push earthworms to the back of their minds, unless bitten. But not so the medium in which worms live: the soil that is central to their existence as subsistence cultivators. This paper attempts a review of these soils, whatever the nature of their fauna. The classification of soil is notoriously difficult and it seeks a compromise. It makes no attempt to present the emic indigenous view because my own Western scientific knowledge of soil inevitably informs any understanding that I have of it. No amount of symbolic jiggery-pokery nor ambiguous structured double-talk can circumvent this epistemological conundrum, to pretend otherwise is dishonest. This is true to the position I think Ralph Bulmer himself so ably adopted in his masterful studies of Kalam natural history, blending his own extensive knowledge of the natural sciences sympathetically with what he came to know of indigenous ideas.

THE WOLA AND THEIR SOILS

The Wola speakers occupy five valleys in the Southern Highlands of Papua New Guinea between the uplands of the extinct Kerewa and Giluwe volcanic massifs. They live in small houses scattered along the sides of the valleys, in areas of extensive cane grass land, the watersheds between which are heavily forested. Dotted across the landscape are their neat gardens. They practise shifting cultivation and subsist on a predominantly vegetable diet in which sweet potato is the staple. They keep pig herds of considerable size. They hand these creatures, together with other items of wealth such as sea-shells and cosmetic oil, around in interminable series of ceremonial exchanges, which mark all important social events. These transactions are a significant force for the maintenance of order in their fiercely egalitarian acephalous society. Their supernatural conceptions centre on the aforementioned beliefs in the ability of their ancestors’ spirits to cause sickness and death, in various other spirit forces, and in others’ power of sorcery and ‘poison’.

The soils of the New Guinea highlands, like those in any region of the world, are the result of complex and ongoing processes. The environmental factors of climate, geology, topography and vegetation have all contributed to them. They have interacted over time, and continue to interact, to produce today’s soils. The time that these soil forming processes have been active has, in pedological terms, been relatively short. And
this is of considerable significance regarding the soils of the region. It is geologically and topographically youthful, and as a consequence it has young soils. Inceptisols dominate the region. They are soils with a cambic horizon but few diagnostic features, an absence of extreme weathering and no accumulation of clay, nor Fe or Al oxides in horizons. They are the embryonic soils of humid regions, thought to develop quickly, due largely to alteration of parent materials.

Soils of other orders cover small areas in comparison and are relatively insignificant. There are some Entisols, the youngest soils, that have little profile development being very recent soils. And there are a few Ultisols, the oldest soils, which have developed where there have been undisturbed conditions for considerable periods such that soil forming processes have proceeded sufficiently to produce these mature tropical soils. They are moist soils that develop under a tropical climate, featuring an argillic horizon and low base saturation (<35%). There are also a few Mollisols, but only young members of this order, represented by permanently immature, truncated soils that occur predominantly on steep slopes where soil movement ensures arrested development. They are dark soils with a soft, crumbly, mollic epipedon dominated by divalent cations and consequently have a high base saturation. Finally, there are localised areas of Histosols, the organic or bog soils with >20% organic matter, developed in water-saturated environments. This gives a total of 5 out of 10 of the USDA (Soil Taxonomy 1975) orders represented in the region, one predominating and the others of minor significance.

SOIL CLASSIFICATION

The first pedologists to study the soils of the region were members of a CSIRO team on a reconnaissance survey to assess land potential and use by the lands systems approach, and they came to the conclusion that they are zonal soils (Haantjens and Rutherford 1964). They considered climate the dominant soil-forming factor; rapid chemical weathering, promoted by the region’s warm and wet climate, was they thought the major factor responsible for its soils. More recently, the soil scientist on the World Bank funded Southern Highlands Rural Development Project (AFTSEMU) has stressed parent material as the dominant environmental factor influencing soil formation (Radcliffe 1986). He is of the opinion that any classification of the soils of the region should take geology as the principal factor in defining soil classes.

In reality it is difficult and distorting to select one feature of the environment as dominant over the others because all play a part in determining a region’s soils. It is more realistic, and less prejudicial, to ascribe equal weight to all of the environmental factors. But this presents us with the complex and bewildering mosaic of soil in the field, undifferentiated according to any feature selected as dominant for structuring a classification around, such as variation in climate, parent material or whatever. This is nearer reality than some contrived classification, for soil is a highly variable and complicated material, essentially unsuited to the kind of hierarchical pigeon-hole classification demanded by Western science. Nevertheless we need to classify to start to understand the world we see. This conundrum has been a perennial problem in soil science: soil is not readily amenable to straightforward classification and yet demands some kind of ordering that we might further our understanding of it, and furthermore, any ordering presupposes some prior knowledge, in selecting those features taken as dominant by which to structure it, which may in turn condition, even determine, subsequent understanding achieved using the classification!

In the face of these somewhat intractable problems, two broad approaches to soil classification have emerged, each having its strong and weak points regarding their accommodation. We may gloss these two approaches as natural classification systems versus artificial classification systems (after Young 1976). The natural systems approach came first. It takes soils as natural products of their environments, their evolution is assumed to depend on the physical conditions that pertain in the regions where they are found. It is descriptive of broad environmental and soil conditions, not analytical of soils themselves. The artificial systems approach to soil classification developed in response to the vague and unscientific taxa definitions of natural systems. It is epitomised by the monumental USDA system (Soil Taxonomy 1975). It is analytical in approach, not descriptive, and focuses on the close definition of different soil types according to observed properties. It reflects the trend in modern science to quantify and define precisely.

Neither approach to soil classification is without its shortcomings. But some classificatory scheme has to be used to order and make sense of the data. In this event, how best to classify the soils of the Kerewa-Giluwe region for discussion? Regarding the classification of soils in Papua New Guinea as a whole, the historical trends related above occurred in a short time span with natural descriptive schemes devised after the last war, largely by CSIRO staff from Australia, giving way in the last ten years or so to the artificial analytic scheme of USDA, which is now the principal classification used in soil investigations in Papua New Guinea. I shall use neither exclusively to order the following account. I have decided to use a hybrid scheme combining features of both natural and artificial approaches, for each has something to recommend it and a rapprochement may exploit their combined strong points and play them off to some extent against their weak ones. And I intend to give a prominent place to the local classification, producing an overtly hybridised cross-
cultural scheme, in contrast to the usual anthropological covert hybridisation. The natural process element draws on previous soil classifications of the region (CSIRO 1965 and AFTSEMU 1986), reordering their classes to some extent and putting no emphasis on any environmental feature. The properties element derives from the soil classification scheme of the local Wola people, supplemented in part by the USDA scheme.

It may at first seem extraordinary that the non-scientific Wola scheme is associated with the avowedly scientific USDA one. But it too goes by objective properties and concerns practical agricultural issues relating to the definition of good, bad and indifferent soils. It is similar in this regard to our culture’s pre-scientific classification of soils which, founded on practical experience, concerned land use, notably ease of cultivation and crop yields on different kinds of soil, relating to our still extant folk classification of soils into heavy and light depending on their clay and sand contents (Wild (ed.) 1988:5, 819). There was no concern about the genesis of soil. The USDA scheme has a similar focus, its central concern being the accurate definition of soil taxa as a prelude to assessing their agricultural potential. The Wola could appreciate this objective, whereas the origin of soil and the processes going on within it are apparently of no interest to them. They are understandably interested, as subsistence gardeners, in knowing, and conveying, something about the agricultural usefulness of a piece of land.

Local subsistence activities also affect the soil, agriculture intervening in natural pedological processes. And giving prominence to the local classification scheme may help us better to appreciate what happens to the soil when people cultivate it, for it will give us some idea of what their experiences are, those whose tradition is founded on practical use of the land. The local scheme is also necessarily concerned with only a small region, known to the inhabitants in intimate detail. It has no universal pretensions, which give rise to enormous, even currently insurmountable, problems in soil science classifications because of the great variability in soils worldwide. It is an advantage to have only a limited range of soils to consider, in a region where there are few marked environmental variations. Another advantage to incorporating local classification schemes into soil surveys is that this should facilitate agricultural extension work and attempts to develop local cultivation practices, introduce cash crops and so on. Indigenous people are more likely to be receptive of suggestions couched in terms of categories they know, modifying and extending on them, than they are foreign ones that appear to assault their understanding and expectations. Furthermore, the consideration of non-scientific classificatory schemes, like that of the Wola, so far as we can apprehend them, may tell us something about the nature of classification and the assumptions that underpin our notions of it. They inform us of different cultural trajectories which may take our idea of classification in different directions. This is particularly pertinent regarding the classification of soil, there being no wholly satisfactory way of classifying it, as we have seen, and new insights may be gained from novel approaches to it.

The Wola notion of classification, for example, is essentially fluid and flexible, which ideally suits it to the classification of a continuously variable medium like soil, unlike the rigid and bounded classes our classifications try to impose on it. The Wola name different kinds of soil according to observed properties (such as colour, texture, moisture, stoniness and so on), and they can combine and modify these endlessly to build descriptive classes, referring to some of this and some of that and so on (for example hundbiy sha araydol ondawp as opposed to hundbiy araydol or hundbiy tongom momonuw araydol haeruw, which broadly translate ‘very stone bright-brownish-clay’ as opposed to ‘stony bright-brown-clay’ or ‘stony bright-brown with gleyed-clay’ etc.).

An elastic classificatory scheme like that of the Wola, which can describe a soil as a mixture of this and that and the other, being none of these types exclusively but laying on the ill-defined boundary between them, shows how contrived is the division of soil into bounded classes. This flexibility results partly perhaps from the soils of the Kerewa-Giluwe region themselves, which starkly comprise a continuum due to the volcanic ash falls that have influenced them to varying extents. The effect of these ash falls is one of gradual variation and not abrupt changes across the region. Their influence depends on the amount of ash deposited, which varies according to such factors as distance from volcanic source, weather at the time of eruptions, slope form, and so forth. The continuous nature of the resulting soil mantle makes it difficult for the profile orientated soil surveyor to draw classificatory lines, as made clear in a comment by CSIRO soil scientists on the distinguishing features of the dominant soil group they identified in the region: ‘In practice these features overlap to a certain extent and distinction in the field can be difficult in places’ (Rutherford and Haantjens 1965:88).

The Wola will name each soil seen as a distinct horizon in a soil exposure as a different kind of soil, but they have no notion that certain sequences comprise named profiles (this is common throughout the Papua New Guinea highlands – see Brookfield and Brown 1963:35, Wood 1984, Radcliffe 1986:80, Ollier et al. 1971, Landsberg and Gillieson 1980). While each horizon comprises a different type of soil and has a name, there is no name for the profile as a whole and hence no attempt to classify soils by different profiles. This is a radical point of difference with Western soil science classifications. According to the Wola scheme soil horizons can occur in any order and whatever this is it merits no particular remark (which is not so eccentric in
a region where frequent landslips can put sub-soil horizons above epipedons). Nevertheless the range of
different kinds of soils, of model types, is fixed.

A further point of difference between Wola and Western soil classifications is that the Wola one has no
hierarchy of nesting classes organised according to certain governing principles (such as environmental
factors, nutrient chemistry, profile morphology, soil age or whatever), which have proved inherently
unsatisfactory in ordering soils and stumbling blocks to the excogitation of some relationships between them.
The Wola have a word for all soils collectively, which is suw, and may prefix the names given to particular
kinds of soil with it (e.g. suw hundbiy, 'ground bright-brown-clay'). It is a word of broad connotation and
may refer to anything from a handful of earth through to an entire geographical region — a commonly heard
phrase is na suw, which means 'my ground' (i.e. my place, where I live) and is often followed by the name of
a territorial location, such as na suw Haenaelinja, 'my place Haenaelinja'. Nearly the entire Kerewa-Giluwe
region is mantled in suw, in a dark brown to black topsoil called suw pombray (lit: ground or soil black),
which according to the Wola is essentially the same everywhere and does not vary in any consistent manner
with changes in the type of underlying sub-soil. While the topsoil comprises a single named taxon in their
classificatory scheme, the Wola make a note of the way it varies in different places, notably in depth, iyba
'grease' content, strength (i.e. friability), stoniness and water content, all important considerations for
cultivation, and may accordingly qualify the term suw pombray (for example, suw pombray buriy iyba na
bidiy, 'strong, black soil with no 'grease'


SOILS OF THE KEREWA-GILUWE REGION

The scheme used, incorporating local discriminations and intimating soil's continuous character, distinguishes
four major kinds of soil in the Kerewa-Giluwe region: clayey soils, sandy/alluvial soils, gley soils, and peaty
soils: (Table 1). The clayey soils dominate the region. They comprise those that derive from weathered
sedimentary rock materials through to those soils derived exclusively from volcanic ash or tephra, and include
the entire spectrum of soils between, that are composed of varying mixtures of both volcanic ash and
sedimentary material, giving a continuous spread. The alluvial soils comprise a continuum too, both of
materials and in age. The older ones consist of redeposited volcanic ash and the recent ones eroded bedrock
and redeposited clayey soil, those in between in age may comprise varying mixtures of both. The sandy soils
are very localised in extent, largely where occasional sandstone beds outcrop at the surface. Any of the above
soils, either an undisturbed one in the volcanic ash — sedimentary rock series or one redeposited as alluvium,
may be subject to wet conditions and become a gley soil, again presenting a continuous soil spectrum. And if
the wet conditions are particularly severe and prolonged, peaty soils of high organic matter may develop. In
summary, the Kerewa-Giluwe region is mantled with soils derived from sedimentary parent materials, variably
affected by volcanic ash, some alluvial redeposition, and some of them affected by high water contents leading
to changes in their morphology.

CLAYEY SOILS

Haen hok arrested soil (Rendoll; Rendzina):

On steep and unstable slopes soil development is arrested and only shallow soils occur, resting directly on
bedrock. They occur predominantly on limestone, and sometimes very calcareous mudstones, being
associated with very steep rocky outcrop limestone slopes, steep colluvial slopes and stony outwash slopes
below limestone escarpments.

The haen hok Rendolls have a black to very dark brown A1 horizon, 10 to 50 cm thick, sometimes turning
dark greyish brown with depth. They have a strong fine crumb or granular structure, becoming perhaps
medium subangular blocky with depth, and of friable to firm consistency. Weathered pieces of limestone and
chert fragments commonly occur throughout the profile, increasing with depth. And some of these soils have
Figure 1: Classification Scheme for the Soils in the Kerewa-Giluwe Region
small amounts of volcanic ash mixed in them. This horizon usually sits directly on a weathered limestone surface of crumbly moist rock, which the Wola call *haen hok*. It is quite distinct from hard consolidated limestone, which they call *hat haen*. And they also distinguish it from the soft whitish putty-like surface covering found on ledges and in crevices on very steep exposures of limestone, that can support small rock plants like mosses, which they call *haen paen*; this skeletal soil-like veneer is uncommon.

These relatively youthful soils are formed as calcium carbonate is gradually dissolved by carbonic acid contained in rain and the products either retained on the exchange complex or leached down through the profile. The process results in a calcium rich clay residue that favours the rapid mineralisation of organic matter, which gives these soils their dark colour and well developed granular structure. The pH of these soils predictably increases gradually with depth, with leaching of some released cations and proximity to calcium rich parent rock. They have a neutral to weakly acid reaction. They are of moderate fertility with high base saturation and have the highest available phosphorus levels for the region (Rutherford and Haantjens 1965:94, 97; Bleeker 1983:113). But this fertility, together with the promising physical properties of these soils, are frequently difficult to exploit agriculturally, even for the Wola who regularly cultivate precipitous sites, because of the very steep and rugged nature of the terrain on which they occur.

**Hundbiy clay soils (Tropept, Humult; Cambisols, Acrisols):**

When a heavy brown clay derived from sedimentary rock underlies the dark *saw pombray* topsoil we enter the *hundbiy* clay class of soils. They are the dominant soils of the region, occupying the greater part of the area under sedimentary rocks. The distinguishing feature of these soils is their heavy clay sub-soil, which is plastic and firm, and frequently imperfectly to poorly drained. They occur principally on steep to moderately sloping terrain away from volcanoes, and also on some gentle colluvial slopes and in depressions such as doline floors and slump alcoves. A variety of sedimentary parent rocks, both consolidated and unconsolidated, underlie them, notably limestones, occasionally fine textured sediments like mudstones and shales. They are soils from which most, if not all, volcanic ash has apparently been stripped by erosion.

The *hundbiy* clay soils have well developed black to very dark grey-brown *A*₁ horizons, usually in the range 10 to 50 cm thick. They are friable and have fine blocky to granular crumb structure. In undisturbed areas a black to dark brown leaf litter horizon and root mat may cover them, and any of the soils described here, called *waip* by the Wola. The *A*₁ horizon overlies a yellowish brown or bright brown *B* sub-soil, the boundary between them being characteristically clear and abrupt (although they may sometimes grade more gently into one another where substantial amounts of organic compounds have moved downwards from the dark topsoil to give an intermediate brown less clayey horizon, which the Wola identify and call *hundbiy sha* (literally brownish, rather than brown)). This *B* horizon has a weakly developed blocky structure, is friable to firm in consistency, and fine textured, usually sticky and plastic. Chert fragments, which the Wola call *aeraydol* (lit: chert-dirt), are quite common in these soils, both in topsoil and sub-soil, sometimes increasing markedly in size and number with depth.

The Wola distinguish two further types of clay sub-soil besides *hundbiy*, according to differences in colour, which they call *tongom* and *kas*. Both occur, they maintain, below a normal brown *hundbiy* horizon, often a metre or more down. They are of limited occurrence. *Tongom* is a white clay, consisting mainly of kaolin, with lesser quantities of mica and illite and some quartz. It is probably evidence of a relic gley soil on the site long ago when drainage was impeded for some reason (or alternatively a diatomaceous earth formed from the siliceous remains of diatoms). *Kas* (also called *omb*) is a bright reddish brown to strikingly bright orange clay which is iron rich, consisting mainly of hepidocrinite with some goethite and a trace of hematite. It is the clay the Wola fired to produce red ochre paint. An associated feature are *omb hul* (lit: kas-clay bones), which are small (up to one or two cms or less across, on average) Fe rich laterite-like concretions found dotted here and there in pockets and sometimes discontinuous strata in *hundbiy* clay sub-soils.

These soils are fundamentally zonal in character, the moderate temperatures and high rainfall of the region dominating their development. The relatively low temperatures, for the tropics, retard the breakdown of organic matter, contributing to the build-up of thick, dark topsoils. Some of this accumulated organic matter is in turn moved downwards by the heavy rainfall and deposited in the *B* horizon, resulting in sub-soils with relatively high organic matter contents. The clay content may increase with depth as a consequence of this movement, and where strong leaching features or the soil is of considerable age, such that leaching has occurred for a very long time, then argillation may be evident (being diagnostic for the USDA Ultisol order — viz Humults). In addition there may be a variable build-up of sesquioxides, giving a continuum related to age and severity of leaching conditions, its modal end-points reflected in the USDA and FAO soil type sequences: Tropept → Humult, Cambisol → Acrisol.

The severe leaching consequent upon the high rainfall not only gives clayey textured sesquioxide enriched soils but also removes bases and gives soils acid to strongly acid in reaction, with a mean about pH 5.0. Nevertheless, while base saturation is low, soil fertility is generally moderate. The mean percentage nitrogen
value is high in the topsoil, as is the mean organic carbon content (at 0.66% and 8.5% respectively, according to Bleeker 1983:93). This may be partly due to volcanic ash in the topsoil, the allophane present in it, together with the relatively cool temperatures, inhibiting organic matter breakdown. This inhibition of organic matter breakdown also results in a high topsoil CEC, which decreases noticeably with depth in the sub-soil. Exchangeable potassium shows a similar trend, having moderate values in the topsoil and low ones in the sub-soil. Available phosphorus levels are also moderate to low, suggesting marked fixation by organic matter. The trend is predictable for older soils, or those subject to intenser leaching due to permeable sub-strata, which fall towards the Humult end of the *hundbiy* clay soil continuum, to have somewhat reduced chemical fertility.

The Wola make wide use of these soils’ fertility, gardening on them extensively. And where they are not under current cultivation they may support large areas of cane grass secondary regrowth. They also support considerable areas of primary and secondary forest vegetation. They are suitable for cash crop development where they occur on moderately sloping accessible land, although they occur largely in less suitable rugged mountainous terrain on moderate to steep slopes. Under continuous cultivation it may prove difficult to maintain their moderate fertility, which is due largely to their relatively high organic matter contents, as evidenced by the traditional agricultural practice of green manuring sweet potato mounds in gardens cultivated repeatedly.

Tiyptiyp volcanic ash soils (*Andepts; Andosols*):

In locations where substantial amounts of volcanically derived ash have accumulated we find soils of the *tiyptiyp* volcanic ash class. They are the second most common soil of the Kerewa-Giluwe region, predomining on its vulcanised eastern and western margins. They occur not only on the dissected slopes and ash plains of volcanoes, but also on mountain slopes and across valley floors some distance away, volcanic ash having been spread widely in the atmosphere across the region (see Pain and Blong 1979). They also occur on alluvially redistributed volcanic ash deposits, as old ash-derived alluvial soils located on fan surfaces and river terraces. All of these soils are formed on andesitic volcanic ash, deposited mainly during the Pleistocene, and their consequent considerable age (about 50,000 years), compared to recent coastal volcanic soils, has resulted in the ash weathering into mature soils characterised by deep, dark topsoils of high organic matter content overlying brown, gritty textured clayey sub-soils with moisture content continuously at field capacity in this wet region (hence the majority of these soils fall into the USDA Hydrandept great group, and in those locations where drainage is better due to permeable strata, and leaching more severe, in the low base Dystrandepts great group).

The *tiyptiyp* volcanic ash soils are usually deep soils, depth depending to some extent on the thickness of the ash mantle. They have black to brownish-black friable A horizons characterised by a high organic matter content. These topsoils are fine to medium textured and have a granular or crumb structure. They have a low bulk density (<0.85 g cm⁻³). They are usually in the range 20 to 65 cm thick, but can be thinner or thicker depending on terrain. They overlie a clay B horizon with a characteristically sandy feel to it, which is diagnostic in identifying a soil as *tiyptiyp* ash to the Wola, who refer to it as *popo hae* (lit: roughness/grittiness stands), the same phrase they use to describe the glasspaperlike surface of scabrous *Ficus quercetorum* leaves which they use to smooth the surface of wooden artifacts. It is not as slippery underfoot to walk on as *hundbiy* clay as a consequence, neither is it as sticky, coming away cleanly from a digging stick or spade when dug whereas *hundbiy* clay sticks tenaciously to them, having the property *paerai mbay* (lit: stick finish). Neither do *tiyptiyp* soils, according to the Wola, become *mondow*, soft sticky liquid mud, but are always well-drained, their porosity being another diagnostic pedological feature of these sub-soils. Nevertheless, regardless of their rapid permeability, these soils are continuously moist due to the region’s wet conditions, and they have been described as structureless as a consequence. But when dried artificially they develop a strong subangular blocky structure. Another related major characteristic is that drying of these sub-soils results in irreversible dehydration of clays into silt and sand sized aggregates. And a further feature is the thixothropic consistency or smeary property of drier sub-soils, where the soil goes from a plastic solid to a liquid under pressure and then resumes its original structure when released. They are usually of friable to firm consistency. The depth of the B horizon can vary from about 30 cm to over 150 cm thick.

The boundary between the A and B horizons is clear and usually abrupt, as in *hundbiy* clay soils. The B horizon is commonly brown to yellowish-brown in colour and merges into a thick olive brown to yellowish-brown C horizon, which is frequently speckled with dark minerals, and is massive and porous. But the nature of sub-soil horizons can vary considerably depending on the extent of weathering. The B horizon may show a clear graduation from a firm highly weathered brown or reddish-brown subsurface layer to a somewhat less weathered yellowish-brown sub-soil. But where weathering processes are retarded, at higher altitudes with their lower temperatures, the volcanic ash parent material is only partially weathered and forms an olive smeary ‘structureless’ compact sandy clay, speckled with dark minerals, faintly to distinctly mottled, more akin to the C horizon of profiles where weathering is more advanced. Soil scientists who have worked in the region have
consequently thought it necessary to distinguish a taxa of high altitude volcanic ash soils separate from lower altitude ones (below 2300 m), called humic olive ash soils (CSIRO) or olive ash soils (AFTSEMU). Further variation occurs in B horizons due to the presence of solid ash, cinders and pyroclastic material in variable amounts giving them a range of stone contents. The Wola refer to these hard bruise-like coloured concretions as tiyptiyp, from which derives the name of the soil saw tiyptiyp (lit: earth/ground volcanic-ash-concretions) abbreviated itself to tiyptiyp. Some soils contain considerable amounts of these hard variously, white and red speckled materials and are very stony, others have few to none in the upper parts of their sub-soils. They vary in hardness from friable and breakable under the foot, called tiyptiyp kolkol by the Wola, to rock hard and unbreakable. The other rock that sometimes features as stones in these soils is huwbipy basalt.

The Wola also distinguish a minor volcanic ash sub-soil group which they call kolbatindiy. It is a red medium textured clay in which fragments of volcanic ash, tuff and so on may occur. It is akin to the kas and tongom sub-soils of hundbiy clay soils in that it occurs deep in the profile (below 50 cm) over lain by tiyptiyp sub-soil; they often occur alternately together giving a series of bluish and reddish-pink Shanklin-sand-like layers. Furthermore the clay content of tiyptiyp soils varies. The Wola refer to those that are clayey as saw hundbiy tiyptiyp, usually abbreviated to just tiyptiyp. or qualified variations of this name depending on the dominance of clay, for example saw hundbiy shasha tiyptiyp (lit: earth hundbiy-clayish tiyptiyp-volcanic-ash) if the clay content is low, saw hundbiy tiyptiyp shasha (lit: earth-hundbiy-clay tiyptiyp-volcanic-ash) for the reverse, and so on. It should be borne in mind that in many locations tiyptiyp volcanic ash sub-soils and hundbiy clay sub-soils may occur overlying one another, even mixed up together, so justifying the interchangeable lego-like nomenclature of the Wola, which can be put together and modified to suit any combination of observed soil properties, whatever their origins (whether a bright-brown clay derives from weathered ash or sedimentary rock or both is not relevant to these people if a mineralogical assay is needed to distinguish between them). The early CSIRO soil survey thought that the situation justified the identification of a transitional soil family (called Ivivar) where thin ash layers overlie sedimentary rock derived clay (Rutherford and Haantjens 1965:88-9) and the AFTSEMU survey of Upper Mendi went on to distinguish a mixed ash-sedimentary soil series (Radcliffe 1986:63). This raises again the continual nature of the soils that mantle the region, with countless intergrades existing between one modal class and another. It should be remembered that while these accounts tend to describe the clayey soils as if they are derived entirely from the weathering and breakdown of either sedimentary parent rocks or volcanic ash deposits, in reality each is more often than not variably influenced by the other – for example, soils derived largely from sedimentary rock weathering may be affected to varying extents by volcanic ash inputs (such as small recent ash falls, which account for the coarser texture of their topsoils compared to their sub-soils and effect a degree of rejuvenation), or older ash layers may be too thin to obscure the influence of underlying rock, or sedimentary derived materials and tephra may have become mixed through soil movement on slopes, and so on.

The continuous variability of soils is promoted further by the differential rates of soil processes featuring in their genesis, illustrated above for volcanic ash soils by the brown and olive sub-soils. The main processes here are the neosynthesis of amorphous clay minerals, high humus accumulation, and geochemical leaching of the mobile products of weathering, notably bases, and desilication. The soil that develops on volcanic ash depends initially on the nature of the extruded parent material. This can vary in composition, but is broadly andesitic, moderately basic in composition. The ease with which it breaks down is significant, volcanic ashes being among the most rapidly weathered of materials, as disordered structures with no regular crystals (Williams and Joseph 1970:122, Birkeland 1974:135-41). Besides differences in time since deposition, variations in soil mineralogical, physical and chemical properties can be attributed to differences in degree of weathering, the principal controlling factors of which are temperature and site drainage – as demonstrated by the more weathered lower altitude brown volcanic soils and less weathered higher altitude olive ones. The depth of ash is also relevant, being a function of both the violence of any eruption and volume of matter expelled, and distance from the volcano, the coarser material tending to fall in thick layers near it, the finer material in thinner layers further away, each subject to different weathering rates. Regardless of these variations, we can generalise and say that volcanic ash not only imparts distinctive properties to soils, but also that they follow broadly similar pathways of formation over a range of climatic and topographic conditions.

In addition to the precipitation of clay minerals following weathering, the characteristics of which determine in some measure the charge and nutrient holding properties of any soil, there is also the concomitant release and movement of nutrient elements, the supply of which determine in considerable measure the soil’s fertility. When released from the parent material these are subject to leaching, and given the porous nature of volcanic ash soils and the region’s heavy rainfall, losses of nitrates, calcium, magnesium and various micronutrients are considerable. The soils are of low base status due to this severe leaching and are consequently generally acid, in the pH range 4.5 to 5.5. Nevertheless, in rich relatively unweathered ash soils, rapid weathering ensures some supply of nutrients for plants – it is only in later stages of development that deficiencies show up. They have high CEC for the tropics (> 25 meq 100g⁻¹), their high organic matter contents being largely responsible
for this, given the importance of pH dependent surface charge in these soils. The high organic matter contents are also responsible for their high nitrogen values. The exchangeable potassium values are low to very low. Available phosphorus contents are low too, these soils having a high phosphate fixing capacity due to their organic matter contents and the amorphous oxides that characterise allophanic clays.

The chemical fertility of these soils is less than might be thought, volcanic soils generally conjuring up images of fertile land. It is highest in the organic rich topsoil, with plant roots tapping some nutrients from the rapidly weathering, rich, mineral sub-soil reserve. Although the fertility of tiyptyp volcanic ash soils is relatively low, with potassium and phosphorus as major limiting nutrients, land use is the same as for hundbiy sedimentary clay soils, which generally have a better nutrient status, with fixation of phosphorus less severe and higher available levels of potassium (Radcliffe 1986:122-3). The Wola garden them the same, and they support a wide range of natural vegetation from primary forest to grassland. Regarding their nutrient deficiencies, the suggestion that the traditional agricultural practice of topsoil mounding leads to pronounced drying and wetting cycles that could promote the liberation of phosphorus and nitrogen (Birch 1960), merits some consideration, for example by those contemplating cash agricultural developments in the region, for the fertility shortcomings of these soils, even where accessible and on moderate terrain, will be a hindrance to cash crop promotion.

SANDY/ALLUVIAL SOILS

Iyb muw alluvial and sandy soils (Fluvent, Psamment; Fluvisol, Arenosol):

The old alluvial soils derived from redeposited volcanic ash, identified by both the CSIRO and AFTSEMU, are distinguished by topographic location (occurring on river terraces, fans) rather than soil properties, the Wola classing them as tiyptyp volcanic soils, which they otherwise resemble, having organic rich black topsoils overlying deep, slightly stratified, ash-derived, brown clay sub-soils. It is recent alluvial soils that the Wola distinguish, calling them iyb muw (lit: water taken), classing them together with sandy soils occurring on sandstone parent material. They class Fluvents and Psamments together on textural grounds, iyb muw being their word for any coarse feeling sediment (in stream bed or soil deposit), from medium sand to gravel, regardless of its mineralogy, colour, origin, and so on. Alluvial soils occur on river flood-margins and terraces, and sandy soils in the few locations where Tertiary sandstones outcrop at the surface unmasked by tephra deposits. They are the least common soils in the Kerewa-Giluwe region, after haen hok rendzinas.

The iyb muw Psamments have a brown A1 horizon of moderately developed medium granular structure and friable consistency. The sandy loam topsoil is thin at 10 cm or so thick. It overlies, and merges into, undifferentiated and structureless sand, which is greyish-olive and orange in colour, and becomes progressively compacted and massive with depth, containing pieces of soft sandstone. The Wola call hard consolidated sandstone bedrock haen naenk (using waterborne pieces, picked up adjacent to rivers, as grindstones for sharpening their axes). The water holding capacity of these porous soils is low. And they have been subjected to little in the way of pedogenesis beyond the formation of the thin A1 horizon with the addition of organic matter from dead plant material, and possibly some decalcification of calcium carbonate contained in any shell fragments present. The mineral fraction is dominated by relatively inert quartz grains.

The iyb muw Fluvents are more variable, although overall similar to the above in having little profile development. These young soils comprise stratified alluvial layers with marked texture variations, deposited by river flooding. The Wola distinguish between them and the above sandy soils, calling them iyb muw pombray or hundbiy (lit: water taken black or bright-brown-clay). They have a brown to brownish-black A1 horizon, with weakly developed medium granular structure, of friable consistency and sandy silt loam texture. The topsoil is of variable thickness, up to about 30 cm but usually thinner. It overlies, and merges into, a structureless C horizon, which is brown to yellowish-brown in colour, becoming mottled greyish-yellow with depth if the watertable is fairly near the surface and gleying induced, as is common in locations adjacent to watercourses, putting the soil into the tongom class (see below). Stratification causes organic carbon content to decrease irregularly with depth (a defining characteristic of the Fluvent suborder). The sub-soil is of variable texture, from sandy silty to clayey, in the latter event the soil falling into the hundbiy clay-like category of saw hundbiysha, rather than the iyb muw one. And it is of firm consistency, and may contain a variety of rounded waterborne stones, some large. The nature of the deposits depends on the energy of the nearby watercourse and its transportational capabilities, which are considerable for the turbulent rivers of the highland Kerewa-Giluwe region. The local people are aware that these soils result from waterborne deposition, for on occasion some of them may be inundated, leaving behind a fresh layer of sediment. Pedogenesis is again limited and centres largely on the development of the A1 horizon through incorporation of decomposed organic matter, and the process of ‘soil ripening’ (Pons and Zonneveld 1965) where draining and evaporation of excess water, aided by plant evapotranspiration, dries and consolidates the soil with the establishment of a regulated moisture regime suitable to a range of plants.
The alluvial iyb muw soils are moderately fertile. Soil reaction is mildly acid at about pH 5.5 and base saturation is high. They have high CEC and moderate nitrogen contents. Available phosphorus and exchangeable potassium values are low, probably because they are largely deficient in the parent materials from which the alluvium derives. The sandy iyb muw soils on the other hand are of low fertility. They are strongly acid, at pH 4.5, and low in bases due to the strong leaching to which their thin topsoils are subject, overlying highly permeable sands. They have a low CEC given their low clay contents, and small mineral reserves too because of it. Their fertility is largely dependent on the organic matter content of their thin surface horizons.

Land use is restricted on both types of iyb muw soil. On the alluvial soil because it is often in locations liable to periodic inundation, although this does not stop some families establishing a few gardens on it (notably of wet-loving taro), and in one or two places it is recognised as a fertile soil particularly worth cultivation. It supports a range of natural vegetation. The sandy soil is avoided by and large because it is known to have low fertility, local people pointing to its thin layer of suw pombray topsoil producing little of the iyba 'grease' essential to plant growth and its compact sub-soil impenetrable to roots. It supports cane grassland and patches of woodland largely.

GLEY SOILS
Pa tongom gley soils (Aquent, Aquept; Gleysols):

Any of the above soils may show gley features in wet locations, except for the iyb muw Psamments. They are more common on the heavier, less well drained hundiby clay soils than they are on the more permeable tiyptyp volcanic ash-derived clay ones, gleyed versions of which merge into the wet olive ash soil types of higher altitudes distinguished by CSIRO and AFTSEMU. The Wola call any gleyed soil pa tongom. It is the third most common soil type of the Kerewa-Giluwe region. The distinguishing features of these soils are their high water contents and gleyed, grey coloured, frequently reddish mottled, sub-soils. Poor drainage conditions, which in turn relate to topography and parent material, largely govern the formation of these soils. They may occur anywhere that the watertable is at, or near, the surface, notably at spring sites, in poorly drained depressions and adjacent to watercourses, and even on ridges and slopes where slowly permeable fine grained parent materials occur like mudstones and siltstones.

The pa tongom gley soils have black to dark brown A1 horizons, 10 to 50 cm thick and silty clay in texture, which are high in organic matter, and sometimes evidence a network of fine reddish brown mottles; wet and sticky, they are seen when drier to be weakly medium to coarse subangular blocky in structure, and friable. They may merge into a B horizon that is prominently brownish mottled grey, or merge directly into a C horizon that is greenish or yellowish grey. The grey gleyed heavy clay sub-soil may also evidence bright reddish brown mottles. It is structureless, very plastic and very sticky. And very slowly permeable, it is waterlogged.

The genesis of these soils relates to the waterlogged conditions under which they occur. The anaerobic bacteria that function in these low oxygen conditions respire by using, in a preferred sequential order, a series of electron acceptors other than oxygen to oxidise energy yielding organic substrates. Two of these acceptors are iron and manganese, compounds of which in the reduced Fe2+ ferrous and Mn2+ manganous states are responsible for the characteristic grey and bluish hues of gleyed horizons. If conditions are part oxidising and part reducing, such that reoxidisation of iron occurs in better aerated zones — common around respiring oxygen releasing plant roots and in large pores where the watertable fluctuates up and down — then reddish brown ferric compounds are formed, giving the soil its distinctive mottled appearance. The Wola themselves associate the mottles in pa tongom soils, which they call handgwick, with plant roots, pointing out that long rusty coloured mottled veins sometimes contain pieces of root fibre; the mottles result, they say, from the rotting of the parent roots and the water held in the channels left in the soil. The reduced conditions also promote the accumulation of organic matter, which is characteristically high in the dark topsoil, the fine dense rootmat frequently associated with the vegetation that occurs under these conditions further encouraging it.

The mineralogy of these soils reflects their origin from one of the above described soils, having present a similar mineral suite, of gibbsite, montmorillonite, metalhalloysite and kaolinite among others. The CEC is good and fertility is moderate (Rutherford and Haantjens 1965:95, Bleecker 1983:39, 68). Acidic, with pH values around 5.0, these soils have low base status. At this altitude they have high nitrogen values, the limiting nutrient under many agricultural regimes. Exchangeable potassium levels are moderate but available phosphorus is again low due to organic matter fixation.

Land use is restricted on these soils. When cultivated they largely support wet-loving crops such as taro and sedge. The Wola rarely dig ditches to drain them to grow other crops. Uncultivated they support a range of natural vegetation, from forest to tall grassland and semi-swamp vegetation. They have little development potential unless drained; they may sometimes be fenced in and used to graze cattle.
PEATY SOILS

Waip peat soils (Folist, Fibrist, Hemist, Saprist; Histosols):

When wet conditions become severe gleyed mineral soils give way to peaty organic ones, for under marshy conditions of year round saturation and waterlogging organic matter accumulates and peat develops. They are characterised by layered organic horizons of varying decomposed plant material. The Wola call this waip, a term they apply not only to peat but also, as cited earlier, to the litter horizon of decomposing vegetation that covers the surface of any soil. It is less a soil taxon to their minds than a vegetative one, referring to rotting vegetation that is necessary on mineral soils to the development of saw pombray topsoil as it disintegrates and supplies the iyba 'grease' required for fertility. Peaty soils occur in two contrasting topographical situations in the Kerewa-Giluwe region: in swampy very poorly drained depressions and on waterlogged seepage sites as bog soils below 3000 m, and on mountain summits above this altitude as alpine peat soils. They cover only a small part of the region.

The waip bog soils of lower elevations are young and feature little, if any soil formation, comprising thick layers of varying depth of black to brown peat, which may range from raw, unripe and open structures to well-decomposed, friable clayey peat, to soft organic mud, all with very low bulk densities. These peat types may comprise a series of layers in varying stages of decomposition down a profile, with the most decomposed in the deepest layer. They may also feature thin layers of tephra or alluvial sediment, which might increase clay content. The waip alpine peats are shallow black to dark brown, well-decomposed peaty clay soils that overlie consolidated or unconsolidated almost fresh rock or grade into weakly developed thin clay mineral B horizons. Some show evidence of humus illuviation, clay content increases with depth and thin iron pan formation, which might be due to volcanic ash admixtures (Bleeker 1983:55).

Pedogenetic processes are markedly reduced in peaty soils. The more or less permanent saturation of them prevents air reaching peat deposits and the consequent lack of oxygen greatly reduces bacterial breakdown of organic matter; mineralisation by anaerobic bacteria is at a considerably lower rate than the supply of vegetative matter which results in its steady accumulation. At higher altitudes precipitation is very high due to the very frequent low cloud cover and evapotranspiration rates are correspondingly low due to the cool climate, such that slopes may even remain water saturated; the low temperatures furthermore greatly reduce the activity of fungi which are responsible for mineralisation processes at high altitudes in the tropics (Mohr et al. 1972), hence there is a considerable build up of organic matter.

The fertility of these soils is moderate. They are acid in reaction, at pH 4.5 to 5.0, and consequently of low base status. The accumulated organic matter results in a predictably high carbon content (a defining characteristic of the USDA Histosol order), which at 15% to 40% is high even for this region where A horizon carbon contents are uniformly substantial. The high organic matter content again accounts for the high CEC. It is also reflected in high nitrogen values; the high C/N ratios that typify these soils, at 10 to 25, suggest a low rate of nitrification and hence small denitrification losses. The exchangeable potassium and available phosphorus levels are again low, as with other soils generally throughout the region.

Land use is restricted on these soils. The inaccessible alpine peats are generally beyond agricultural use, experiencing low cloud and frosts, and remain under montane grassland, featuring alpine species, and patches of mossy forest. The lower altitude waip bog soils support a range of hydrophytic natural vegetation, including sedges, reeds, shrubs and bog woodland. They are beyond cultivation without considerable reclamation work, notably the digging of drainage ditches to reduce water levels. The people living in the upper Mendi valley have drained and cultivated some of the peat soils in the lake Egari area, so inducing mineralisation in the topsoil layers (Radcliffe’s 1986:67 Wimteh soil series), but by and large the Wola infrequently drain these soils, which anyway cover only a small part of their region (unlike elsewhere in New Guinea, in the Baliem and Wahgi valleys for instance, where people engage in extensive drainage measures, doing so since antiquity in some places – Heider 1970:42; Bleeker 1983:60-1; Steensberg 1980:85-7; Golson 1977). The soils may have high chemical fertility when cleared and drained, as indicated by investigations of those under commercial tea and coffee cultivation on plantations in the Western Highlands (Drover 1973), and have development potential with appropriate capital investment.

In conclusion, regarding the cross-cultural hybridisation of knowledge, let me finish on worms. It is noteworthy that the Wola assert that none of the above classes of soil has to their knowledge a higher or lower gogay worm population than any other, nor think such a consideration significant, unlike us (e.g. Humphrey 1984:33-7). We hold it as common knowledge, stemming from Charles Darwin’s (1881) classic studies of earthworm activity, that worms are evidence of a good soil and promote fertility, since they assist in the breakdown of organic matter, by consuming it together with some mineral fraction to produce an argillaceous humus (passing a staggering 15 tons an acre through their bodies – Brady 1984:230), and loosen the soil with their burrows, so improving its structure and promoting aeration and drainage. But the Wola will have none of it. They do not associate an abundance of earthworms with a good and productive soil. Earthworms, they insist, have nothing to do with soil productivity. And they may have a point, for increases in the size of
earthworm populations have been found to correlate negatively with sweet potato yield in the Tari basin (Rose and Wood 1980). Again an intermingling of apperceptions may prove more fruitful to furthering our overall understanding of phenomena. It is certainly nearer to the anthropological achievement than assumptions about translating one culture into categories intelligible to another.

NOTES

1. I am grateful to the Natural History Museum, London, and A. Neboiss of the National Museum of Victoria, for identifications.

2. Two systems of soil classification enjoy wide international recognition in the tropics and elsewhere; they are the USDA (1975) and the FAO-UNESCO (1974) systems.

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