On the origin of Planosols – the process of ferrolysis revisited

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Abstract
Planosols have been recognized as a Major Soil Group right from the beginning in the legend of the FAO Soil Map of the World. Also in WRB system it maintained that position at Reference Soil Group level on the account that a major pedogenetic process, ferrolysis, is underlaying the severe stagnic properties that characterize this group. With the recent introduction of Stagnosols in WRB it appears that a serious overlap has been introduced at Reference Soil Group level. This paper aims to throw new light on the genesis of Planosols, drawing from new soil surveys conducted in the south-western Ethiopian highlands. The conclusion is that it is highly unlikely that 'ferrolysis' can be called in to explain the genesis of Planosols in the Ethiopian highlands. As Ethiopia is one of the mainstays of Planosols, it is suggested that WRB rethinks its strategy on soils with stagnic properties as there is room for rationalization.

Key Words
Planosols, Stagnic properties, Ferrolysis, Stagnosols.

Introduction
International soil correlation of Planosols
The Reference Soil Group of Planosols holds soils with surface horizons that are bleached and light-coloured or have a stagnic colour pattern, show signs of periodic water stagnation and abruptly overly a dense, slowly permeable subsoil with significantly more clay than the surface horizons (Driessen *et al*. 2001). They typically occur in seasonally or periodically wet plateau areas, often above normal flood levels or nearby rivers or estuaries. Occasionally they occur on gentle or very gentle slopes, but usually the geographical extent is limited in these landscape positions.

In the old European literature these soils are mainly referred to as pseudogley soils or as clayey Podzols, however, neither of these soil groupings required an abrupt textural change from the bleached horizon to the underlying dense horizon. The U.S. classification of 1938 was the first to use the term Planosols; the present Soil Taxonomy (Soil Survey Staff 2006) includes most of the original Planosols in the Albaqualfs, Albaquults and Argialbolls. In the revised legend of the Soil Map of the World, Planosols are recognized as a major soil at highest level. Also in the World Reference Base for Soil Resources, Planosols are accommodated under the set of soils with stagnating water together with the Stagnosols (IUSS Working Group WRB 2007).

Soils with stagnogley under WRB
The WRB (IUSS Working Group 2007) accommodates four Reference Soil Groups at the highest level, which have an assemblage of stagnogley as one of the key features: in key order they are the Solonetz, the Planosols, the Stagnosols and the Albeluvisols. It is acknowledged that stagnogley is not part of the key definition in Solonetz and in Albeluvisols, however in most cases it is a major feature in these soils. Stagnosols had a turbulent history in the WRB. In the first draft of WRB in 1994, they were proposed as a reference group, however they did not make it in the 1998 version. The Working group WRB at that time did recognize the importance of stagnogley as an important soil feature. The rationale for not keeping the Stagnosols in was the fact that 'stagnogley' as such is only a consequence rather than a major pedogenetic process. This was in conflict with one of the basic principles of WRB to follow as much as possible a soil-genetic approach in the delineation of major soil groupings.

In line with the above-sketched rationale the following pedogenetic processes were considered important for recognizing the soils with stagnic properties:

- Solonetz: sodification, peptisation of the clay minerals which move into a very compact argic horizon. Upon solodization of the Solonetz it is hypothesized that the distinct textural change and the stagnogley is enhanced by a ferrolysis process at the fringe between the E and the B horizon (natric horizon).

- Planosols: the ‘abrupt textural change’ from coarse textured surface soil to finer subsoil can be caused by:
    - ‘Geogenetic processes’ such as sedimentation of sandy over clayey layers, creep or sheet wash of lighter textured soil over clayey material, colluvial deposition of sandy over clayey material, or selective erosion whereby the finest fraction is removed from the surface layers, and/or
    - ‘Physical pedogenetic processes’, such as selective eluviation-illuviation of clay in soil material with a low structural stability, and/or
    - ‘Chemical pedogenetic processes’ notably a process proposed under the name ‘ferrolysis’, an oxidation-reduction sequence driven by chemical energy derived from bacterial decomposition of soil organic matter (Brinkman 1970).
- Albeluvisols: the genesis of Albeluvisols roots back to Late Glacial times, more particularly to the Middle and the Younger Dryas periods and its respective interglacials:
    - Argilluviation (mobilization and translocation of clay) during interglacials;
    - Formation of polygonal albeluvic tonguing during the last glacial period, including compactation of the outer sphere of the soil polygons leading to the so-called ‘closed box system’ which eventually results in strongly expressed stagnogley on top of the compacted agric horizon. It was also inferred that the process of ferrolysis could have enhanced the textural contrast in Albeluvisols, however this claim was refuted by Van Ranst and De Coninck (2002), who proved that this process does not take place in soils with albeluvic tonguing (Albeluvisols) and in soils with stagnic colour pattern in Western Europe.

During the international conference on soil classification in 2004, at Petrozavodsk (Russian Federation, organized by the Institute of Biology, Karelian Research Centre), the decision was taken to take the Stagnosols on board again in WRB. This decision was implemented in the published 2006 and 2007 (electronic) versions of WRB during the IUSS congress at Philadelphia, USA. At the same time a call was made for fundamental research which should elucidate the above-mentioned pedogenetic processes and especially the process of ferrolysis.

On the origin of the abrupt textural change in Planosols – Ferrolysis revisited – case of SW-Ethiopia
As Planosols are most extensive in relatively hot climates with a strong seasonal variation in rainfall, they are commonly occurring in association with Vertisols in presently sub-humid to semi-arid climates. In these zones all variations intermediates between Vertisols and Planosols occur such as Vertisols with a thin layer of grey or light grey, silty upper soil horizon of variable thickness, overlaying heavy clay, with silty material “etched in” along cracks into the underlying clayey material. If this layer of silty material is only few centimetres thick, the Vertisol still stands and this coarse material is tell-tale of some important pedogenetic process which is not sufficiently understood.
Soilscapes with associations of Planosols and Vertisols are very common throughout the Ethiopian highlands, all developed from massive occurrences of Tertiary flood basalts under a sub-humid moisture regime.

Materials and methods
In the framework of a major research project in Gilgel Ghibe catchment in the Omo-River basin, we studied a typical Planosol profile near Dedo (Figure 1). Soil samples were taken at eight depths, with more frequent sampling near the point of abrupt textural change.
The samples were analyzed in the Laboratory of Soil Science at Ghent University for the following characteristics:
- ✓ Micromorphology of samples taken in Kubiëna boxes;
- ✓ On disturbed samples:
    - Standard characteristics such as pH, texture, organic carbon, CEC and exchangeable base cations and anions
    - Total element composition
    - XRD of powder samples of fine earth fractions
    - XRD of separated silt and clay fractions
    - Phytoliths (opal-A) analysis

Phytoliths (amorphous silica precipitated in plants) were extracted from plants and soil by qualitative gravimetric methods (Herbauts *et al.* 1994) and quantitative alkaline methods (Saccone *et al*. 2007). These two extractions will allow us to analyze the morphology of phytoliths in plant and soil and infer the relative contribution of phytoliths on the total content of amorphous silica in the soil samples.

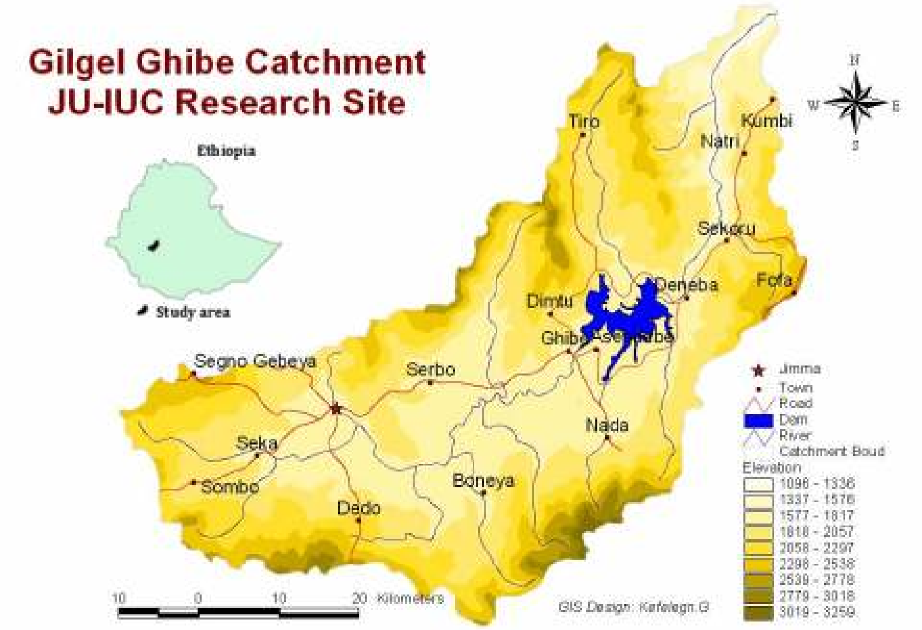

Figure 1. Situation map of Gilgel Ghibe catchment

Results

Under the microscope many phytoliths were observed in the silty and bleached upper layer (0-34 cm), while only few phytoliths were detected, mainly in cracks, in the clayey soil material (Vertisol) underneath (Figure 2).

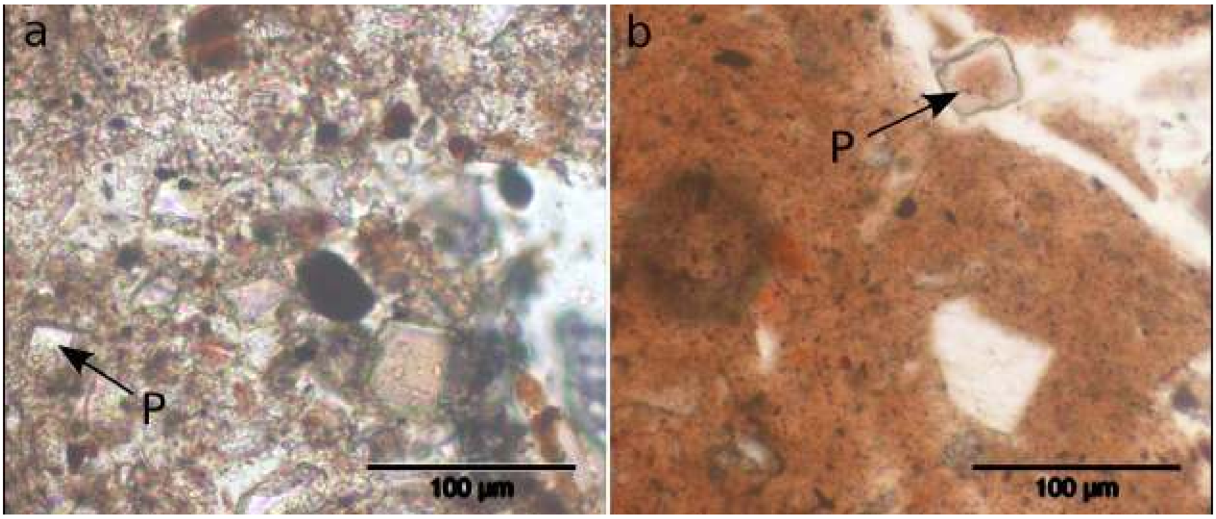

Figure 2. Groundmass in plane polarized light of (a) the silty and bleached upper layer containing many phytoliths (P), and (b) the clayey soil material (Vertisol) underneath having only few phytoliths mainly in the cracks.

XRD analysis showed that quartz and feldspars are the major mineral components in the upper soil layer. On the other hand the clayey soil material is dominated by swelling 2/1 phyllosilicate minerals, and has a much lower quartz content and only traces of feldspars in the fine earth fraction. The transition between the two soil materials is, besides an abrupt change in texture, also indicated by significant changes in chemical characteristics and total elemental composition. At the transition (depth around 34 cm), the O.C content increased from 0.5 to 0.9-1.2% suggesting a buried topsoil or migration of organic matter, while the strong increase in CEC, from 10 to 40-60 cmol(+)/kg, and also in exchangeable base cations clearly reflects the difference in mineralogical composition. Soil pH (in H_2O) and base saturation gradually increase with soil depth, but are higher than 5.3 and 57% in all horizons, respectively. The relatively high pH and base saturation at present means that the actual conditions are not inductive for ferrolysis . The upper soil layer has much higher total SiO_2 (> 70%) and Na_2O (1.2-1.4%) contents compared to the clayey subsoil (50-55% SiO_2 and 0.5% Na_2O), indicating the dominance of siliceous components and feldspars in the upper layer. At the transition, there is a clear increase in the Al_2O_3, CaO, MgO, and H_2O (loss on ignition) content, due to the smectitic minerals. Through scanning electronic microscopy (SEM), the morphology of amorphous silica in soils was compared with the morphology of phytoliths extracted from plants to make assumptions about the origin (biogenic or pedogenic) of the high content of amorphous silica in the horizon above the textural change.

Conclusions

From the results of this analysis, it seems highly unlikely that ferrolysis could have been a process under the given circumstances. Counter-indicative to ferrolysis at the point of abrupt textural change are the relatively high pH, presence of a sizeable reserve of weatherable minerals (mainly feldspars) and presence of open 2:1 phyllosilicates. The thin sections disclose high concentrations of phytoliths which are indicative of a high level of past and present biological recycling in the horizon above the textural change. Alternative geogene hypotheses are put forward in order to explain the variability of the Planosols and Vertisols in the Gilgel Ghibe catchment. The study of the dynamic of amorphous silica in the soil-plant system provided essential information to better understand the influence of biogenic and pedogenic processes on the soil properties. Last but not least, based on the analysis, recommendations are made for rationalizing the soils with stagnic properties in WRB. It seems to us that there is too much of soils with stagnic properties in the WRB system since the re-introduction of the Stagnosols. If the fundamental questions raised on the hypothesis of ferrolysis under the circumstances of the Ethiopian soilscape also apply to Planosol situations elsewhere in Africa, one could argue to subdue the Planosols to lower level in the WRB system.

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