Modelling in-situ soil profile evolution

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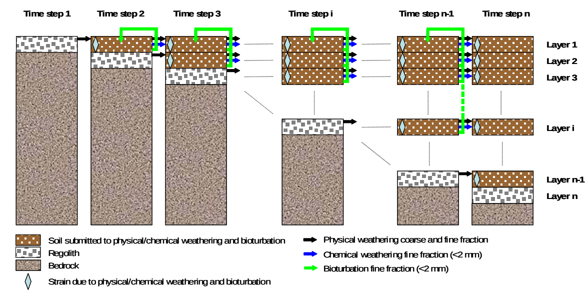
INTRODUCTION AND AIMS

Models of soil genesis are of great importance in assessing the effects of global change on ecosystems. Most models of pedogenetic processes account for chemical reactions and fluxes at the horizon scale and are difficult to extrapolate to the landscape scale. Regolith formation at the catena and landscape scale, represented by the evolution of soil depth through time has been modelled (Minasny and McBratney, 2001). Improvements to this model require further development of the evolution of the soil material released by the bedrock. The aim of this study is a first attempt to further develop this model at the profile scale by taking into account soil-forming processes, such as the physical and chemical weathering of primary minerals, as well as bioturbation.

STRUCTURE OF THE MODEL



1 - BEDROCK LOWERING RATE: REGOLITH PRODUCTION

Bedrock lowering rate negative exponential function of soil depth

$de_i = de_0 \exp(-b.dS_i)$ (Minasny and McBratney, 2001)

de_i: bedrock lowering rate ($m.yr^{-1}$)
de_0: potential weathering rate of bedrock at dS=0 ($m.yr^{-1}$)
b: empirical constant (m^{-1})
dS: soil depth (m)

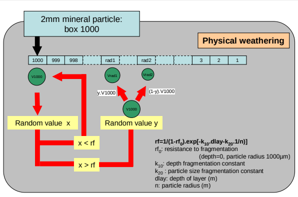
2 - PHYSICAL WEATHERING OF THE COARSE FRACTION

Breakdown to smaller fragments according to first order kinetics

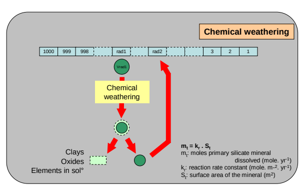
$dcf_i / dt = -k.cf_i$

cf_i: volume of coarse fragments in the size fraction i (m^3)
k: empirical constant

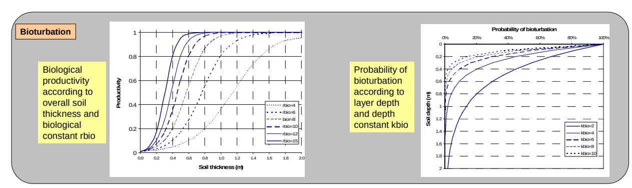
3 - PHYSICAL/CHEMICAL WEATHERING AND BIOTURBATION OF THE FINE FRACTION



Physical weathering of minerals
Redistribution among size classes (Legros and Pedro, 1985) according to resistance of mineral to fragmentation.
Particle fragmentation = negative exponential function of soil depth and particle size.



Chemical weathering of minerals
is a product of reaction rate constant and surface area of the mineral (White *et al.*, 1996). Calculation of primary mineral mass weathered and, if relevant, mass secondary minerals formed.



Bioturbation of the fine fraction
Consequence of earthworm/ant/termite activity. Homogenisation of topsoil + fine fraction (<2 mm) translocation from subsoil to topsoil (Müller-Lemans and van Dorp, 1996).
Quantity of fine fraction translocated from one subsoil layer related to:
- biological productivity (related to soil thickness)
- activity follows a negative exponential depth distribution

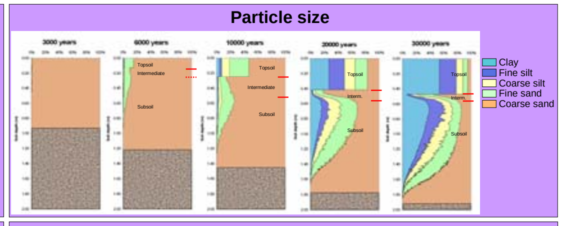
EXAMPLE: GENESIS OF SOIL WITH A STONE LAYER

Example based on detailed soil weathering study (Schroeder *et al.*, 2000)
Meta-gabbro:
- 49% plagioclase
- 44% hornblende
- 7% quartz

} known mineralogical composition

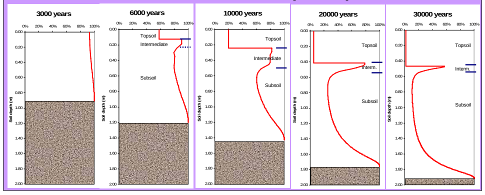
Weathering pathways (+ stoichiometry):
- dissolution plagioclase → 0.71 kaolinite group
- dissolution hornblende → 1.02 kaolinite group + 2.18 goethite

Particle size

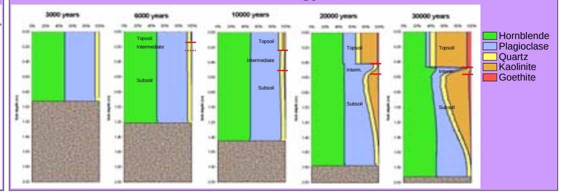


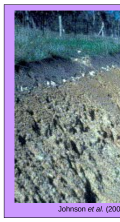
- **t=3000 years**: no horizonation.
- **t=6000 years**: topsoil developed, intermediate horizon initiated: more coarse fragments, slight difference in particle size.
- **t=10000 years**: topsoil thickening, 3 horizons clearly distinguished for coarse fragments and particle size, slight mineralogical distinction.
- **t=20000 years**: topsoil still thickening, intermediate horizon thinning, strongest contrast between the 3 horizons.
- **t=30000 years**: topsoil only slightly thickening, intermediate horizon further thinning and starts to 'disappear' as a result of further CF fragmentation and 'shortage'.

Coarse fraction (>2mm)



Mineralogy




Johnson *et al.* (2005)

➔ Genesis of a stone-layered soil that accords with mechanisms of soil development recently described by Johnson *et al.* (2005).

CONCLUSIONS

This simple in-situ, soil-profile model takes into account 3 major pedogenic processes : physical and chemical weathering, as well as bioturbation. The soils modelled show horizonation, and their properties, including particle size, bulk density, mineralogy, elemental composition, strain,... can be tracked through time.

Improvements to the model are manifold and could include for example addition of organic matter. The next step is to apply this model at the catena, then at the landscape scale to consider other redistribution processes such as erosion and deposition.

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