Supply-limited weathering regime in a tropical shields basin (Ogooué River basin, Gabon)

What is the variability of weathering/erosion rates with respect to lithological effect and geomorphology on two tropical basins (Ogooué and M’Bei rivers, Gabon)?

J. S. Moquet¹,²*, J. Bouchez¹, J.-J. Braun³,⁴,⁵, S. Bogning⁶, A. P. Mbonda⁷, J. P. Bricquet³, S. Carretier³, V. Regard³, M.-C. Paiz⁸ and J. Gaillardet¹

¹Institut Physique du Globe Paris, CNRS, Paris, France; ²Institut des Sciences de la Terre d’Orléans, CNRS, Orleans, France; ³Geosciences Environnement Toulouse, IRD-CNRS-UPS, Toulouse France; ⁴Institut de Recherche pour le Développement, Yaoundé, Cameroon; ⁵Institut de Recherches Géologiques et Minières, Yaoundé, Cameroon; ⁶Université de Douala, Cameroon; ⁷Centre National de la Recherche Scientifique, Libreville, Gabon; ⁸Hydrosciences Montpellier/IRD, Montpellier, France; ⁹The Nature Conservancy, Libreville, Gabon

Corresponding author: jean-sebastien.moquet@cnrs-orleans.fr

Funding: EC2CO project « RALTERAC » (PI : JJ Braun)
What is the variability of weathering/erosion rates with respect to lithological effect and geomorphology on two tropical basins (Ogooué and M’Bei rivers, Gabon)?
Shield weathering: the Ogooué basin case

Ogooué basin (Central Africa Craton)

3 geological/geomorphological regions:
- Plateau Bateke: sand (pure quartz) - tectonically quiescent and low erosion rates.
- Northern sub-basins: granites - deep lateritic soils, tectonically quiescent, low erosion rates.
- Southern sub-basins: Mixed lithology - uplift activity - erosion.

Lambaréné

Temperature: 28°C
Rainfall: ~ 2000 mm yr\(^{-1}\)
Runoff: ~ 665 mm yr\(^{-1}\)

Project RALTERAC (J.J. Braun-IRD)

(Bogning et al., Remote Sensing, 2018, Advances in Space Research, 2020)
Sampling campaign

September 2017

24 sampling (including 18 tributaries):
Water, suspended sediments, river bank sand

Data available: daily discharge at Lambaréné, rainfall (TRMM), MNT (SRTM90)

In situ measurements:
- pH: 4.63-7.62
- Conductivity: 5-78 µS.cm⁻¹
- Water temperature: 22-28°C

Lab analyses:
- Major and trace elements
- $^{87}\text{Sr}/^{86}\text{Sr} + \varepsilon\text{Nd}$ (only sediments) (not presented)
- $^{10}\text{Be}$ on sand
Chemical weathering deduced from the water chemistry

Atmospheric inputs

→ Classical Cl concentration decrease from the Ocean (*ex*: Congo: Negrel et al., GCA, 1993)
→ No evaporites inputs → Cl is used for atmospheric correction
→ Excellent correlation between Si and $\text{HCO}_3^-$  
→ Homogenous silicate source for almost all samples  
→ silicate weathering dominate the solutes and $\text{CO}_2$ consumption
Silicate weathering ~ 80% of the Ogooué and Mbei solutes

High contrasts in solutes concentration

Climate effect (dilution) or geomorphological effect?

TDS (Total dissolved solids) = Na\(^+\) + Ca\(^{2+}\) + Mg\(^{2+}\)+K\(^+\)+HCO\(_3\)^\(−\)+SO\(_4\)^\(2−\)+Cl\(^−\)+SiO\(_2\)

→ Silicate weathering ~ 80% of the Ogooué and Mbei solutes
→ High contrasts in solutes concentration
→ Climate effect (dilution) or geomorphological effect?
Pure sand basins
Basins under erosion?
Northern sub basins
Southern sub basins

Contrasted weathering fluxes: 0.45 to 33 t km\(^{-2}\) yr\(^{-1}\)
Lowest: Pure sand sub-basins (Plateau Batéké)
Highest: Southern sub-basin → higher relief / higher slope

Erosion rate probably control weathering rate in this shield environment

→ 2.5% of the western Africa coast TDS flux
(Milliman and Farnsworth, 2011)

Weathering rate distribution

Weathering control: geomorphological setting?
Plateau Batéké
Northern Ogooué sub-basins

Shield basin compilation:

Runoff is not the first order control of shields weathering
Ogooué sub-basins: highest and the lowest weathering rates

Ogooué basin: No relationship between weathering rate and runoff
Rainfall is almost homogenous and the basin is geomorphologically contrasted

Shields can exhibit very contrasted weathering regime!
Denudation rate based on sand $^{10}$Be

- **Oggoué mainstream**: main erosion area from plateau Batéké to plain
- Very low erosion rate in the eastern part of the northern and southern basins (< 10 t km$^{-2}$ yr$^{-1}$)
- Low erosion rate in the rest of the basin but
  
  $$E_{\text{southern basins}} (20-50 \text{ t km}^{-2} \text{ yr}^{-1}) > E_{\text{northern basin}} (12-20 \text{ t km}^{-2} \text{ yr}^{-1})$$

Preliminary results:
The error associated to the main Ogooué channel can be > 50% due to error propagation at confluences budget.
Two contrasted regimes:

- **Transport limited regime** for Mbei, Northern and southern tributaries
- **Lithological effect** (sandstone erosion –depleted in mobile element) for Plateau Batéké basins
  - Ogooué mainstream: mixing behavior
Weathering rate (water chemistry):

→ **Shields** exhibit a significant weathering budget
→ Contrasted weathering fluxes
  → Mainly controlled by geomorphological characteristics
  → Runoff is not the first order control

**sand ¹⁰Be denudation**:

→ Main area under erosion: Ogooué mainstream (river bank sedimentary material?)
→ E northern basin < E southern basin
  → Denudation deduced from sand mainly reflect mainstream behavior

**W vs D regime**:

Two regimes can be distinguished:

→ Transport limited regime in Mbei, Northern and southern sub-basins
→ Supply limited due to lithological effect in plateau Batéké and mainstream.
  → Cratonic basins do not follow a unique weathering regime