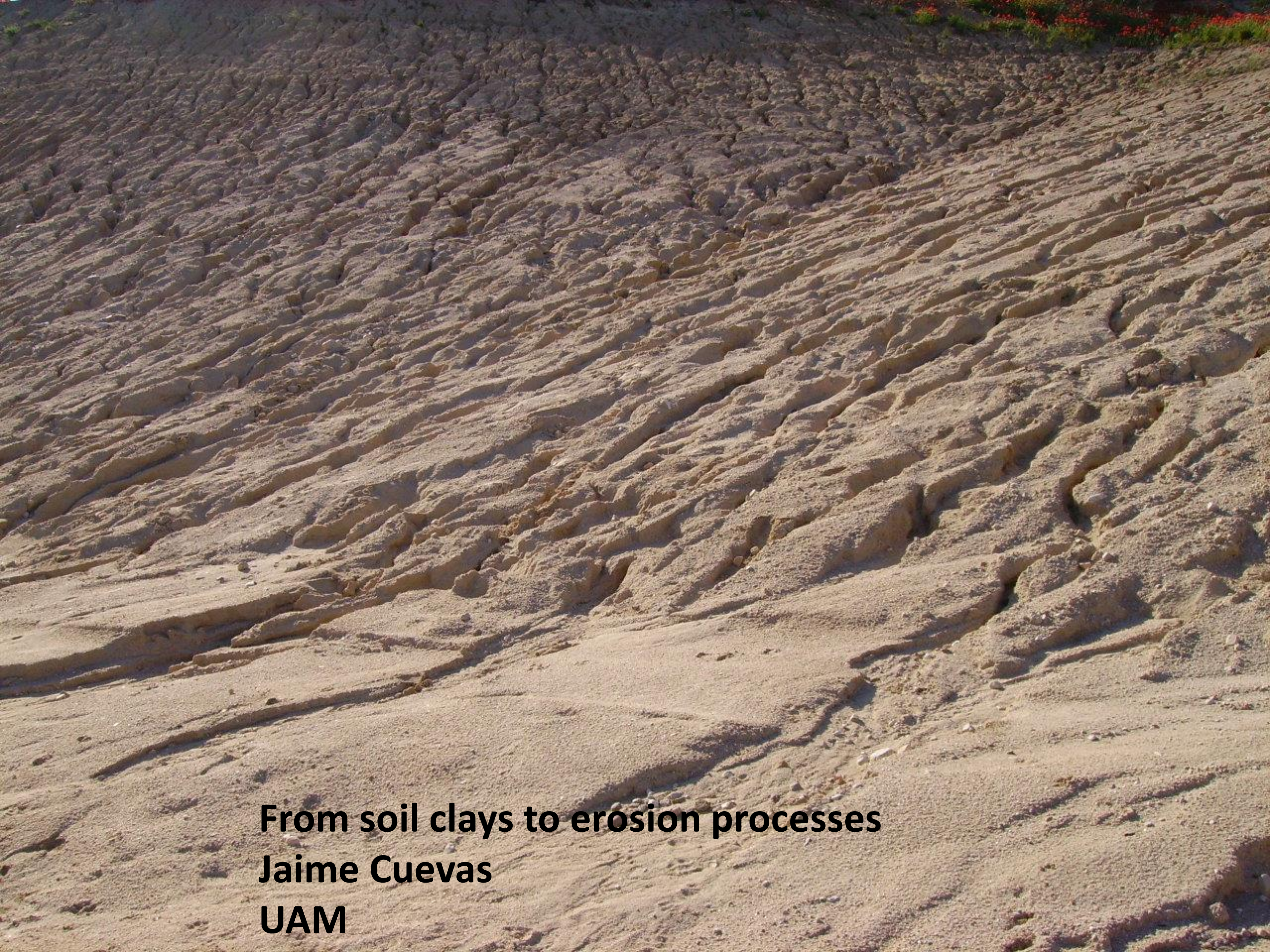

From soil clays to erosion processes
Jaime Cuevas
UAM

## Clay erosion in safety assessment in Deep Geological Repositories (DGR)

Compacted bentonite will produce colloidal particles (Fissures; active fractures)

Evaluation of clay loss
impact in barrier integrity and long term performance
Potential RN transport

## Soil erosion:

Unconfined state

Favorable conditions for colloidal release (rainwater physical impact; stream flow)

So, what can we learn from soil erosion studies to be applied in the SFA for DGR?

**The objective (as CIEMAT team suggested)**
**Motivate new thinking/ideas to study clay erosion**

http://paqquita.blogspot.com.es/2014/09/pon
ton-oliva-carcavas-alpedrete-s-p.html

# Summary

Soil aggregates stability: analogies to clay buffer erosion and colloid release control?

Physical-chemical and structural properties of different clay minerals:
Clay systems erodibility

Factors influencing aggregate stability in soil clay systems: free oxides and organic matter

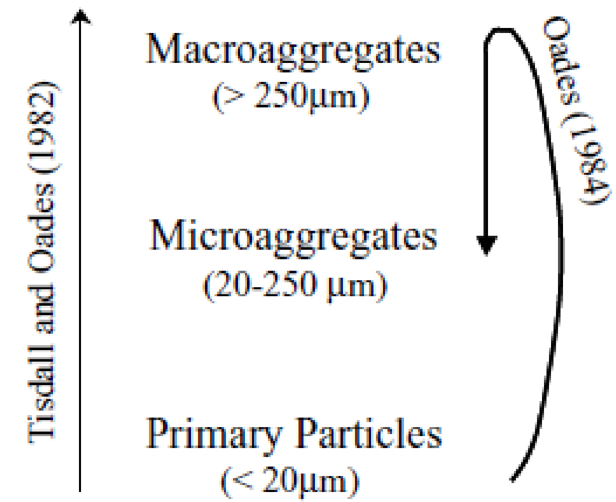
# Ideas

# 1. Soil aggregates stability:
# analogies to clay buffer erosion and colloid release control?

| Type of treatment | Form of sample | Expression of the result | Authors |
|---|---|---|---|
| | 3–5 mm | MWD* | Yoder (1936) |
| | <2 mm | % > 200 µm | Hénin *et al.* (195 |
| Wet sieving | whol | | & I |
| | 1–2 | | ser |
| | 2–3. | | Ta |
| | 1–2 | | y ( |
| | 4–5 | | |
| Raindrops or rainfall | 2–9 | | |
| | 5–8 | | |
| | whol | | |
| Ultrasonic dispersion | 4–5 | | ren |
| | 4–5 mm | inter-aggregate pore volume | Grieve (1980) |
| Immersion | 3–5 mm | qualitative | Emerson (1967) |
| Dry sieving | <4 mm | MWD | Kemper & Chepil (1965) |

MWD:
mean weight diameter

Sum of mass fraction remaining on each sieve after sieving x mean aperture of the adjacent mesh : calculated range between 25 µm-3.5 mm using the a set of six sieves




Le Bissonais (1996)
Aggregate stability and assessment of soil crustability: I. Theory and methodology
EJSS,47,425-437

# Aggregate Breakdown Mechanisms

| Mechanism | Slaking | Breakdown by differential swelling | Breakdown by raindrop impact | Physico–chemical dispersion |
|---|---|---|---|---|
| Type of forces involved | Internal pressure by air entrapment during wetting | Internal pressure by clay differential swelling | External pressure by raindrop impact | Internal attractive forces between colloidal particles |
| Soil properties controlling the mechanism | Porosity, wettability, internal cohesion | Swelling potential, wetting conditions, cohesion | Wet cohesion (clay, organic matter, oxides) | Ionic status, clay mineralogy |
| Resulting fragments | Microaggregates | Macro and and microaggregates | Elementary particles | Elementary particles |
| Intensity of the disaggregation | Large | Limited | Cumulative | Total |

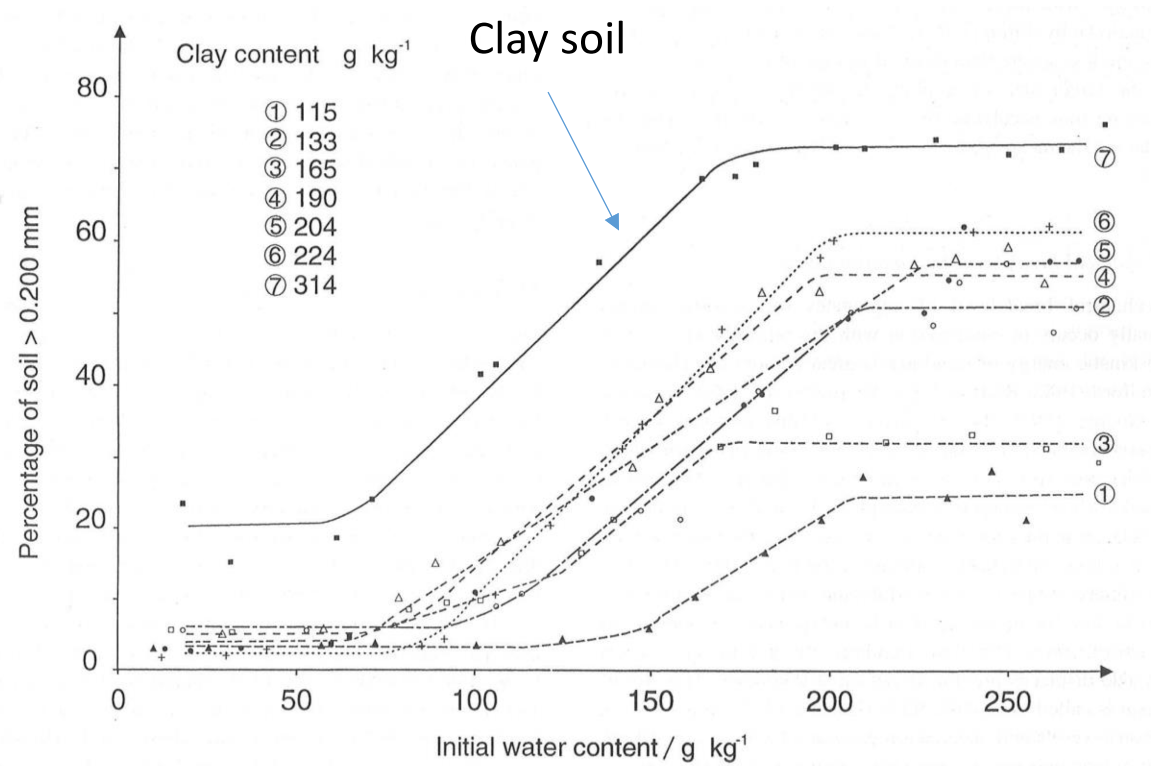
Slaking: rapid wetting

Differential swelling

Raindrop impact

Physico-chemical dispersion

Le Bissonais (1996)



# Analogies to clay buffer erosion and colloid release control?

## Colloid formation

**In static systems: slaking?**
Rapid wetting of dry compacted bentonite: aggregates fragmented and dispersed by means of tensions generated by trapped air.
…the increase of clay particles in solution is initially rapid…

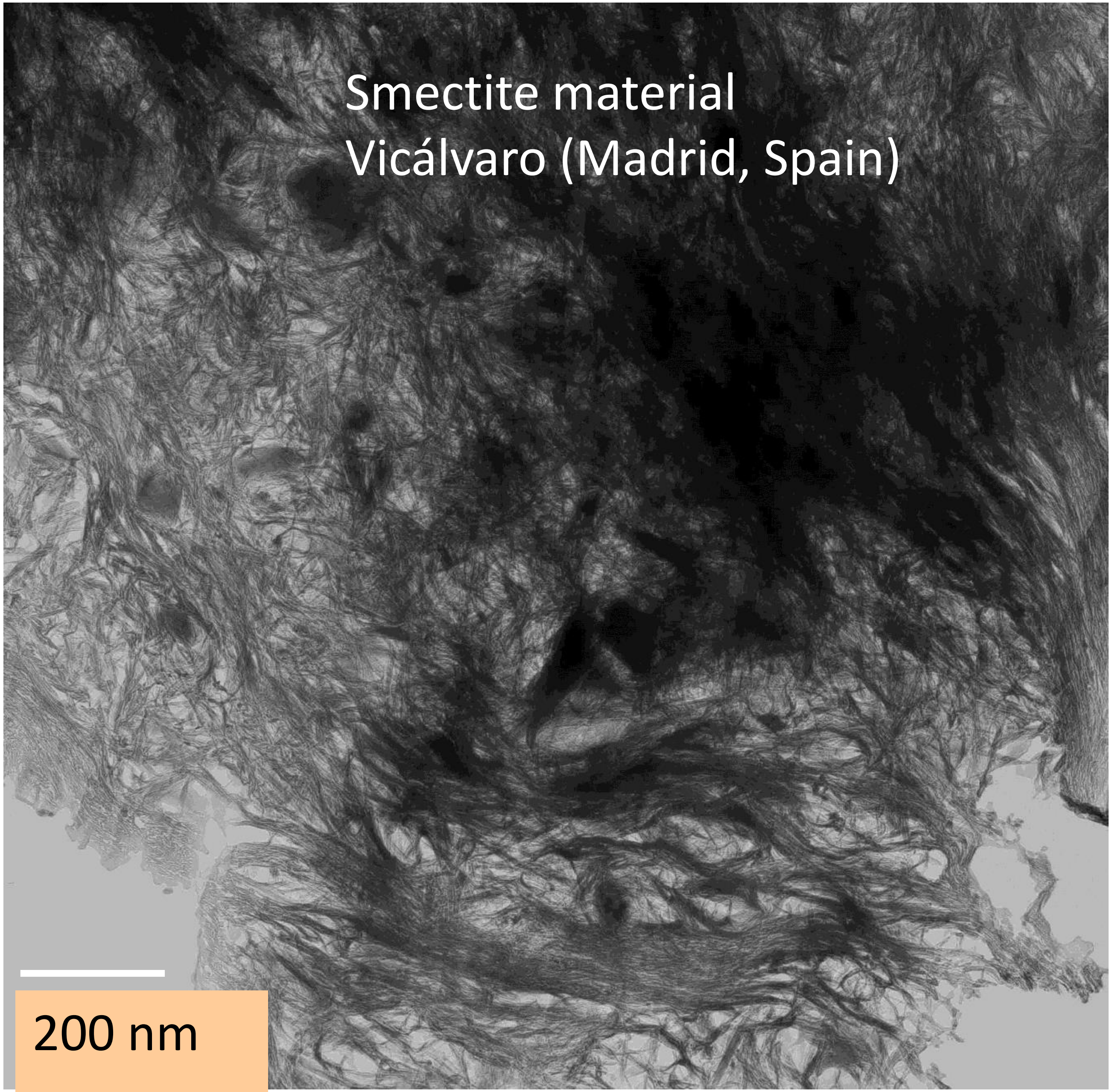
Differential swelling (micro-aggregates breakdown)

The bentonite loss in a static system is not to be continuous
(crusting?: fissures clogging: self-healing)

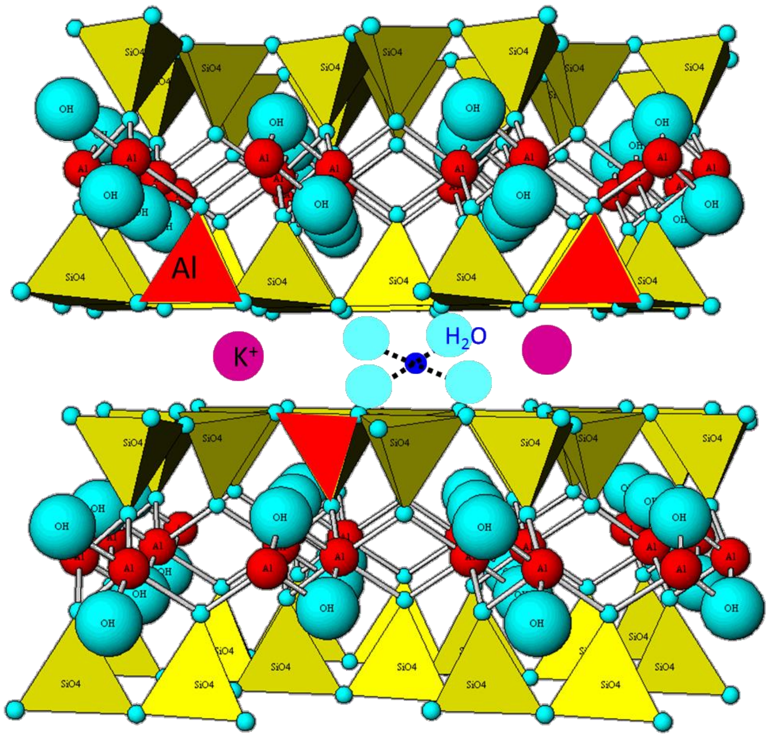
**The dynamic system:** flow perturbations; physicochemical dispersion
Role of water chemistry; exchange complex, mixed materials ( free oxides, organic components)

**Aggregate stability**:
porous filters < 1µm pore size do not allow the observation of particles release,
<u>Indicators for micro (nano)-aggregate integrity measurements could be developed</u>

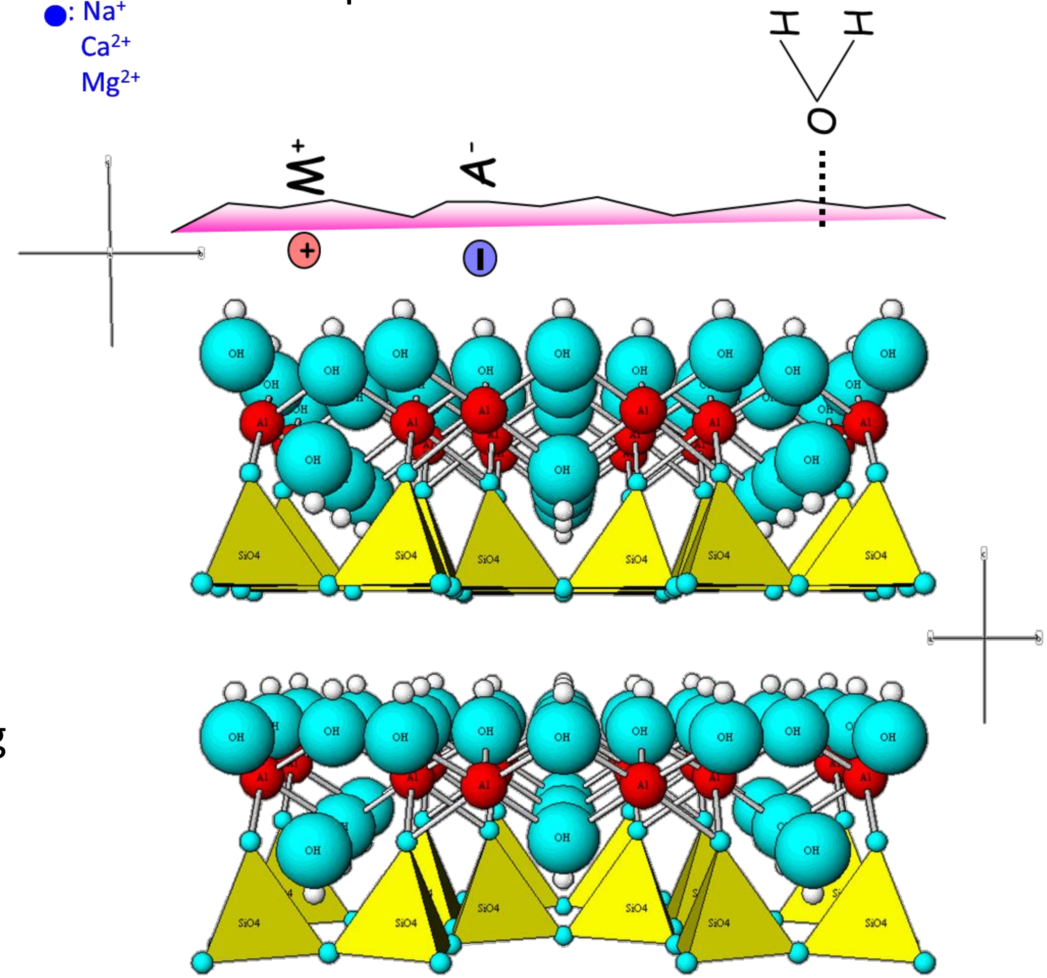
**2. Physical-chemical and structural properties of different clay minerals: Clay systems erodibility**



# CLAY MINERALS
# sheet 2:1 (illite $K^+$, smectite ●)




Oxide Surface attachment
amphoteric surfaces




Soil organic matter (SOM)-M+-binding
Organic cations binding R-NH4+

# CLAY MINERALS
# sheet 1:1 (kaolinite/oxides)

# CLAY SYSTEM: ALSO A MATTER OF SIZE/SHAPE INTERACTION BETWEEN CLAY PARTICLES

**A** Schematic structure of clay aggregate

**B** Scanning electron micrograp of clay tactoid

NEVE YA'AR (MONTMORILLONITIC, 63% CLAY)

NETANY

TUN

1 to 2 µm

Mean weight diameter and total soil loss values for various studied soils (after Wakindiki and Ben-Hur, 2002)

| Soil | | Mean weight diameter | | Total soil loss ($kg\ m^{-2}$) |
|---|---|---|---|---|
| Location | Mineralogy | In fast-wetting test (mm) | In runoff (mm) | |
| Tunyai | Kaolinitic | 2.80a[a] | 0.12a | 0.33a |
| Neve Ya'ar | Montmorillonitic | 0.25b | 0.03b | 1.24b |
| Netanya | Montmorillonitic | 0.31b | 0.20c | 1.14b |
| Molo | Non-phyllosilicate | 0.84c | 0.18c | 0.75c |
| Njoro | Non-phyllosilicate | 0.87c | 0.21c | 0.80c |

[a] Different letters in a column indicate significant differences among soils, $P \leq 0.05$.

**SLAKING** → (In fast-wetting test)

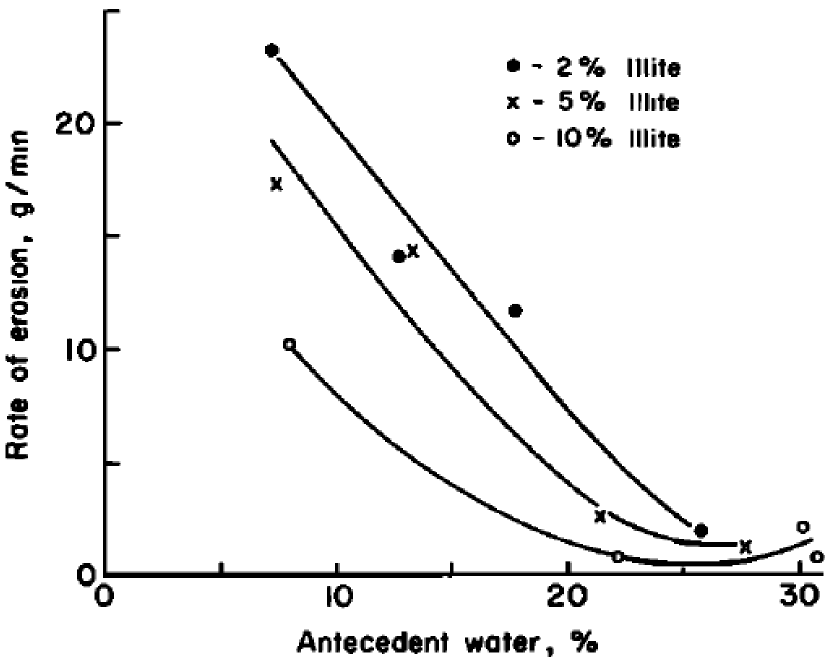
**SEAL FORMATION UNDER RAIN FLOW** → (In runoff)

M. Lado, M. Ben-Hur / Applied Clay Science 24 (2004) 209–224

# CLAY SYSTEM: ERODIBILITY/(no oxide/SOM interaction)

## STABILITY OF COHESIVE MATERIALS AGAINST EROSIVE FORCE OF FLOWING WATER

**Stability increased for 2:1 clay soil mixtures** and for oriented kaolinite (1:1) matrix: function of clay content**, previous water content**. **ERODIBILITY INCREASED WITH TEMPERATURE**



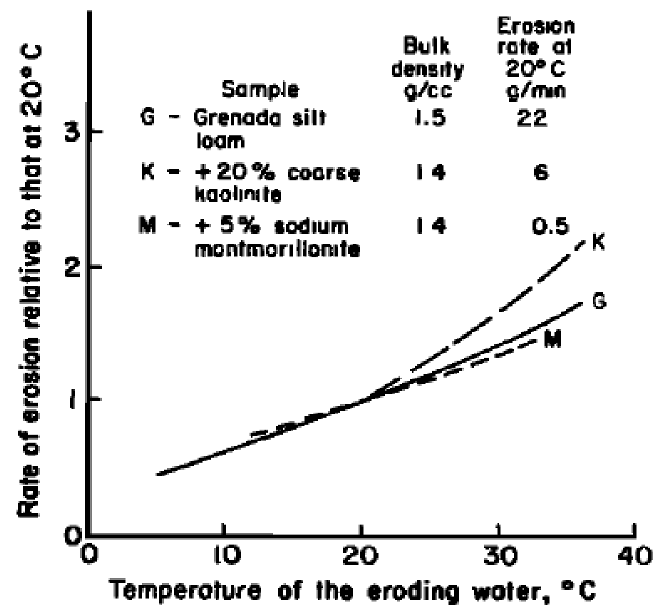




Fig. 1. Influence of temperature on erodibility of Grenada silt loam with admixtures, compacted and tested at 10% water.

E.H. GRISSINGER (1966)
Resistance Of Selected Clay Systems to Erosion by Water
Water Resource Research,2, 131-138

But: Erodibility (Interrill flow) is high for smectitic soils and low for kaolinitic-oxidic soils (Reichert et al., 2007)

# 3. Factors influencing aggregate stability in clay systems: free oxides and organic matter (SOM).

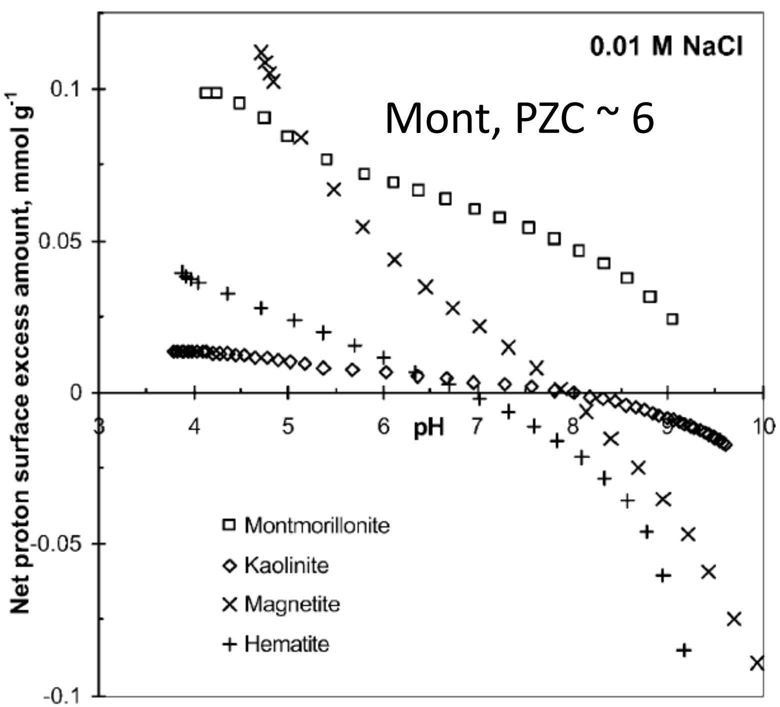



Fig. 1. pH-dependence of net proton surface excess amount determined by acid-base titration for clay minerals and metal oxides at 0.01 M ionic strength.

Proton Surface Excess acid- base tritration PZC

Tombácz et al., 2004, Organic Geochemistry, 35, 257-267

**Small amounts of Al or Fe oxides improve flocculation of clay systems:** more effective for 1:1 systems at near the PZC of the oxides (7.2-8 Fe; 9.5 for Al).

(Goldberg and Glaubig, 1987; CCM, 35, 20-227)

In soils of mixed mineralogy (illite, smectite, kaolinite**), the removal of amorphous and crystalline oxides increases the clay dispersivity**.

But

**The removal of SOM decreased clay dispersivity**. Macro-aggregates are destroyed, SOM favors particle repulsion

Goldberg et al., 1990; Soil Science, 3, 588-593.

# CLAY SYSTEMS: organic matter (SOM) + Biomass interaction
# Macro-aggregate stabilization specific to 2:1 clay systems.

J. Six et al. / Soil & Tillage Research 79 (2004) 7–31 19

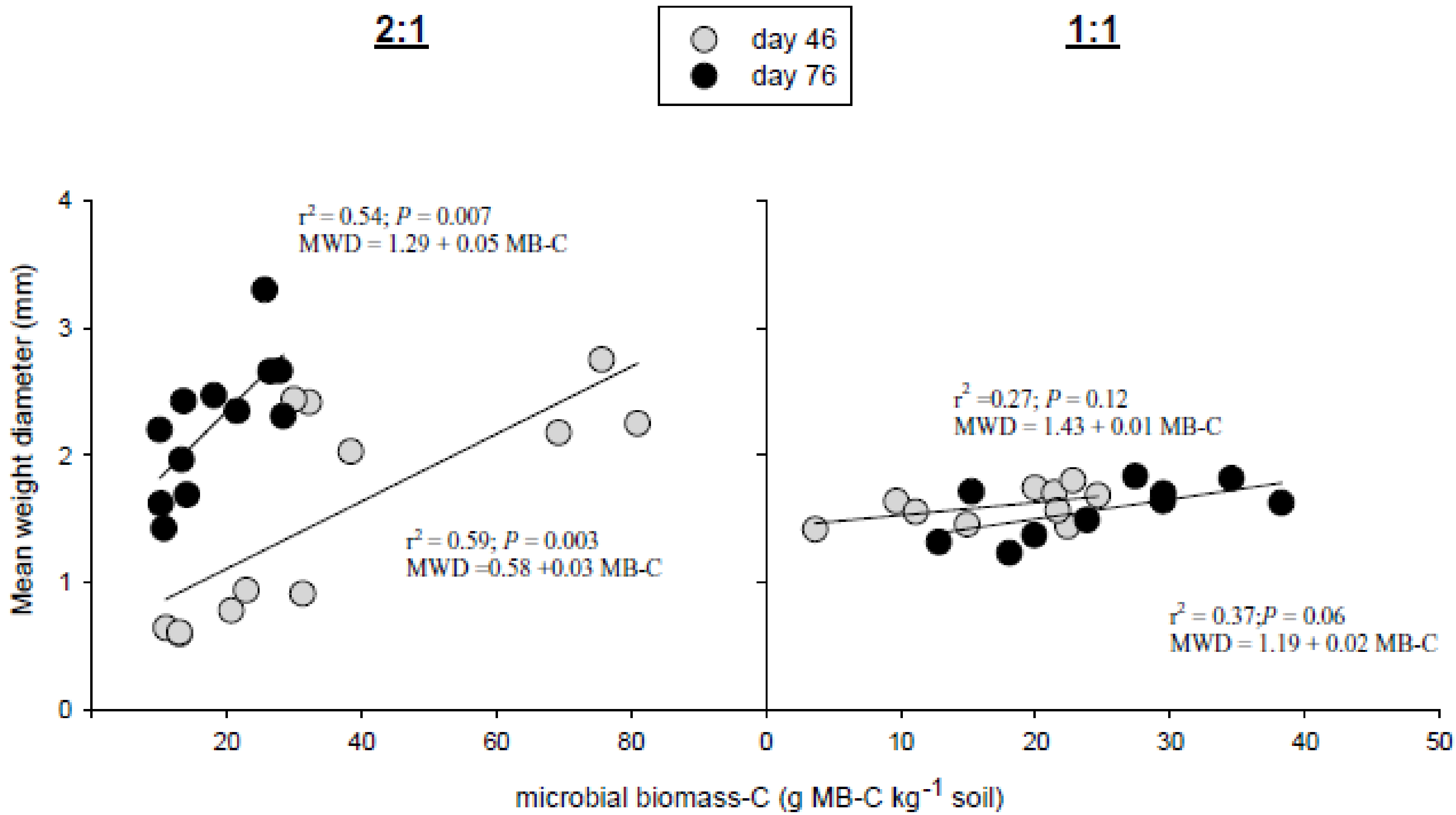



Fig. 7. Relationship between microbial biomass C (g MB-C $kg^{-1}$ soil) and aggregation (expressed in mean weight diameter) in a Mollisol dominated by 2:1 minerals and an Oxisol dominated by 1:1 minerals and oxides. Data adopted from Denef and Six (2003).

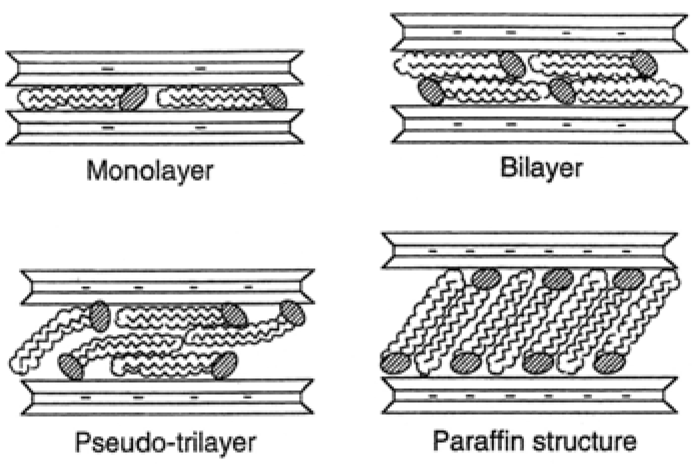
Illite, smectite selectively support/adsorb biopolymers related to microorganism activities

# Ideas

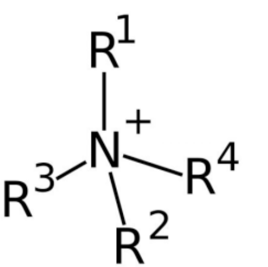
Materials design: Erodibility control.

i.e.: **Iron oxides could control the PZC and favor aggregate stability at erosive interfaces**. Could be useful to apply oxide (i.e., magnetite or other iron oxide nanoparticles to control erosion at the interfaces?

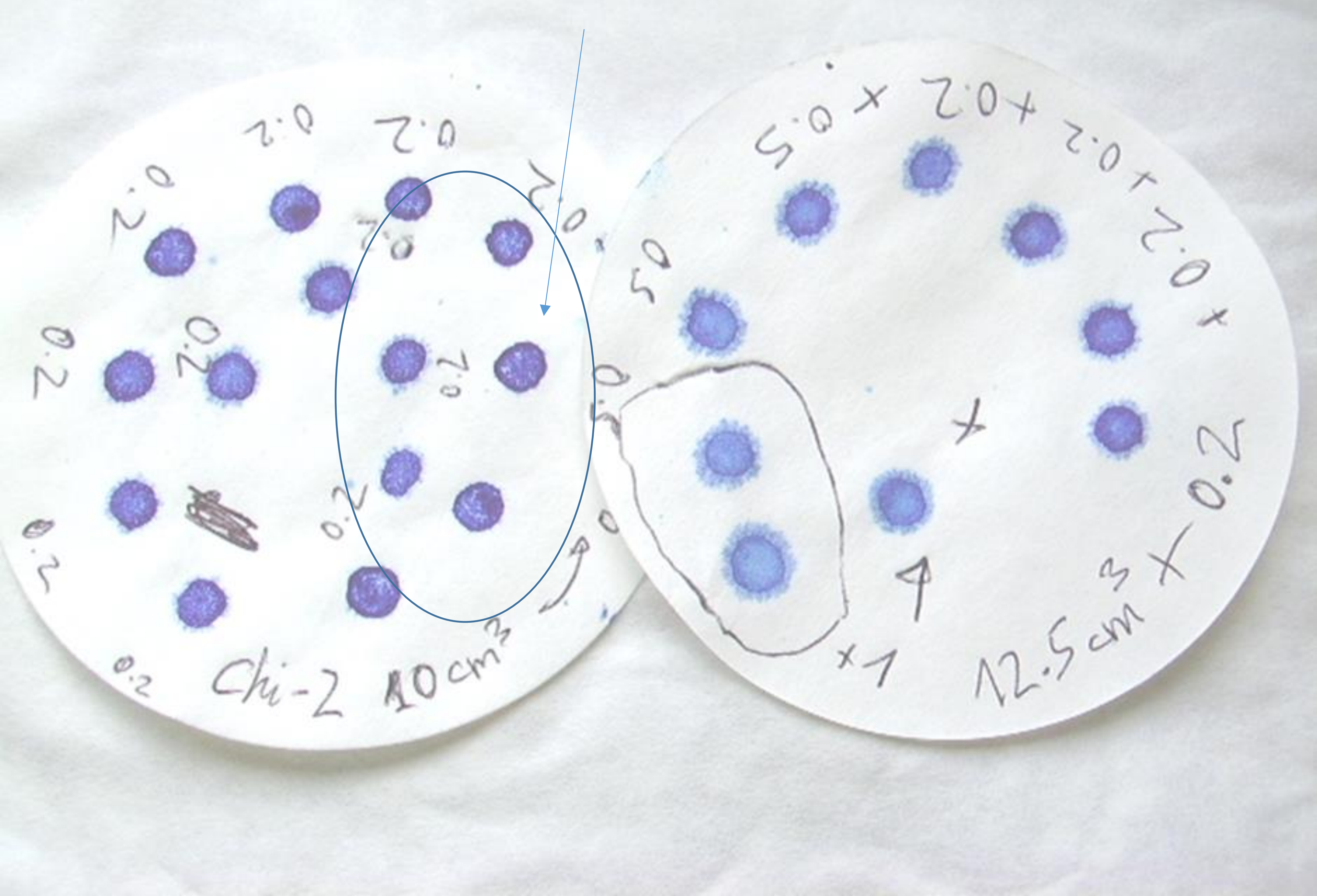
**Erosion measurements in field experiments: aggregate/particle detachment tracers:** organo-nano clays
i.e. Mentler et al., (2009). Organophylic clays as a tracer to determine erosion processes. Geophysical Research Abstractys, 11.: (detectable in 0.3 µg/L)

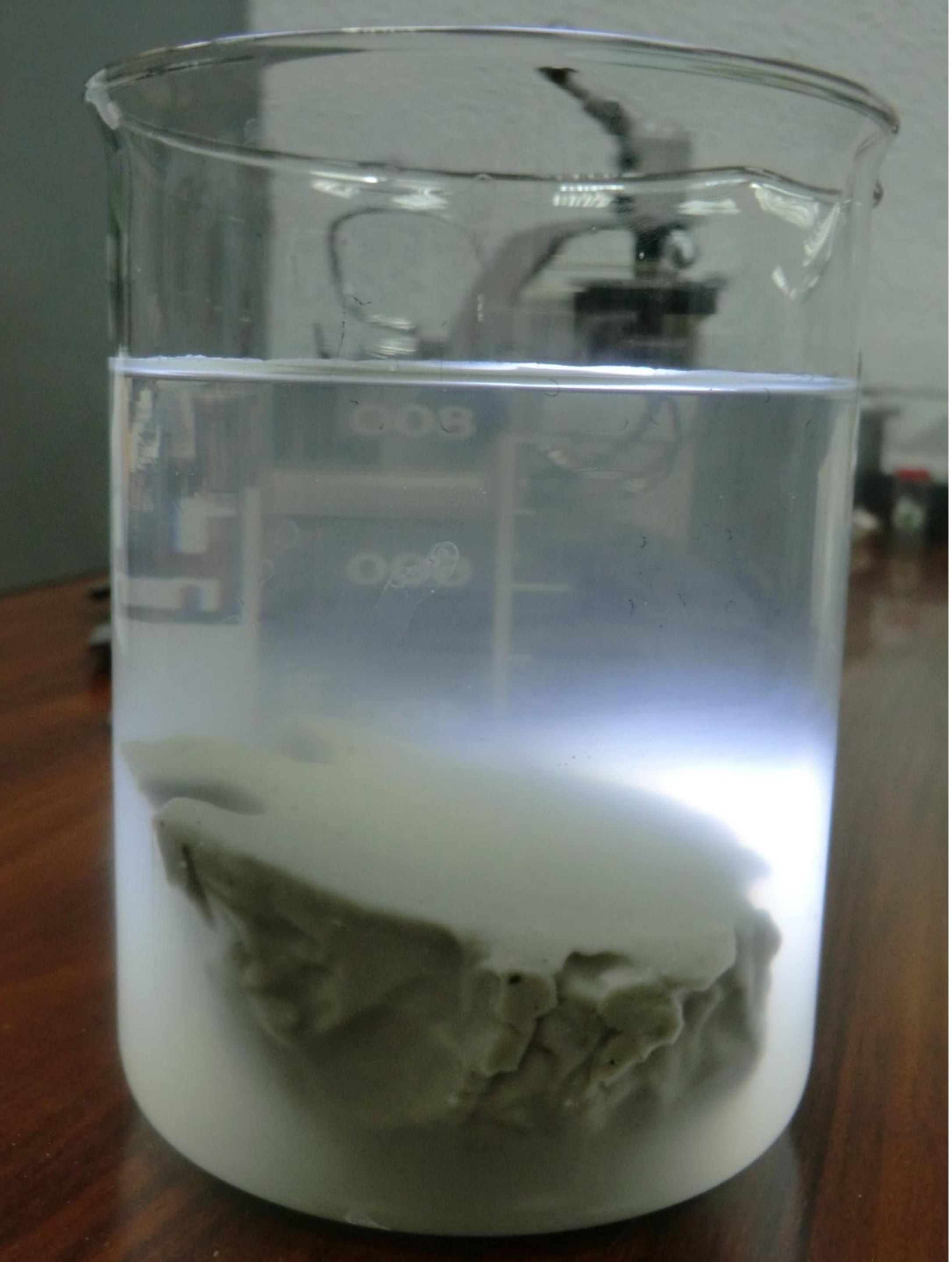



Qutubuddin and Fu 2002



Methylene blue (MB) -montmorillonite particles could be used also as tracers for erosion: at low concentration forms stable aggregates





Thank you for your attention

Particle mediated transport linked to field erosion:

Cs at Fykushima

Antibiotics/pharma compounds

Potential applications of nanosized organoclay synthesis products

A choice for field or larger scale colloid transport evaluation?