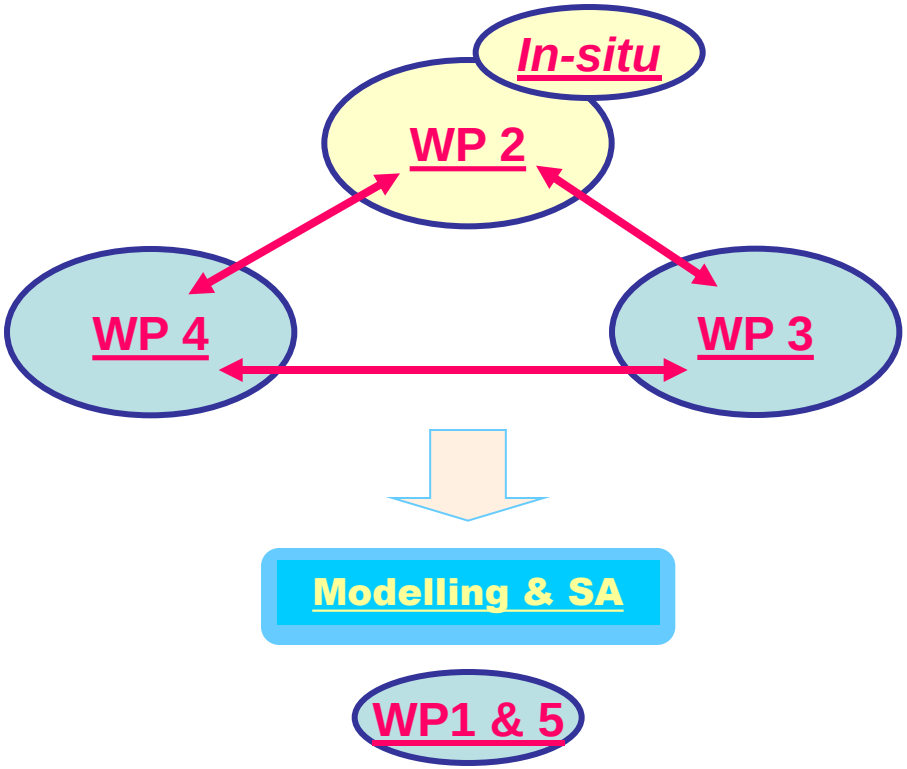
CIEMAT Outcome

WP2: EROSION

Ursula Alonso, Tiziana Missana

CIEMAT work was planned with these premises:



The comprehension of processes in each WP must be focused to a global need: input of data for qualitative and quantitative models description in SA.

Work packages are totally inter-dependent. Collaboration and result transfer between them is needed.

Coherence in the selection of experimental conditions is always needed even the experimental approach is different.

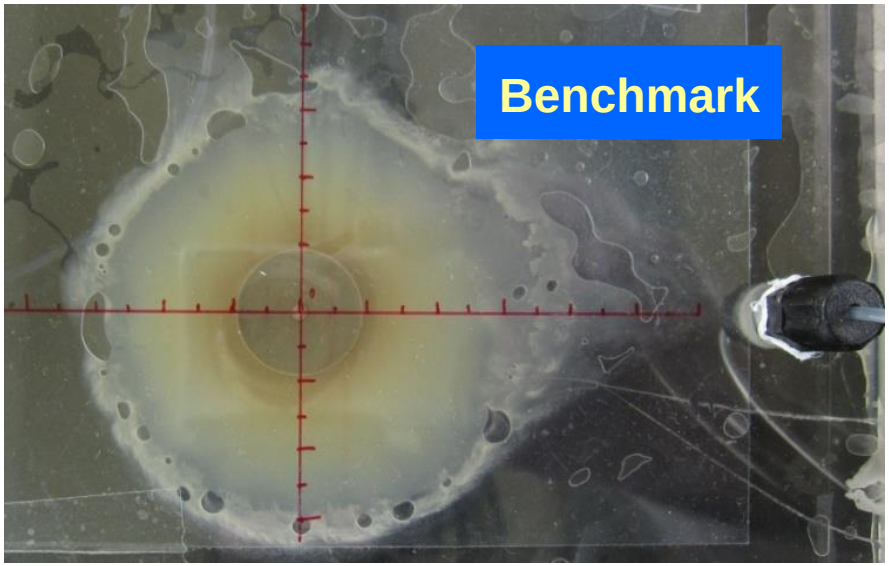
Final aim: to understand realistic scenarios.

Issue	Safety case position at start of BELBaR	Outcome
Mechanisms of erosion of clay particles from the bentonite surface	***Erosion will cause a loss of bentonite buffer performance under some conditions.*** *This may lead to corrosion failures of the canisters.* *Corrosion failure leads to the largest impact on risk, a less pessimistic approach may have significant* ***impacts on the calculated risk.***	Mechanisms of clay colloid release (WP2 output). Improved quantitative models with new data (WP5 output).

CIEMAT outcome

Issue	CIEMAT Outcome
Mechanisms of erosion of clay particles from the Bentonite surface: • **Mechanisms** of clay colloid release (WP2 output). • Improved quantitative models with **new data** (WP5 output).	✓ Clay hydration ; swelling ✓ Gel formation ✓ **Favourable conditions** ✓ Extrusion ✓ Mobilisation (***available paths***) ✓ **Na-bentonite** (**1.6 g/cm^3** in **DW**): 7.3E-2 kg/m^2

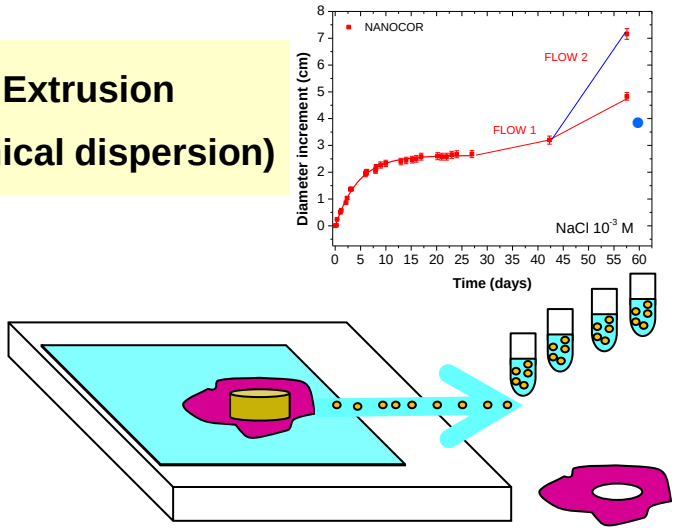
Nanocor clay 1.4 g/cm^3, Na-bentonite & NaCl 10^{-3} M; Flow conditions



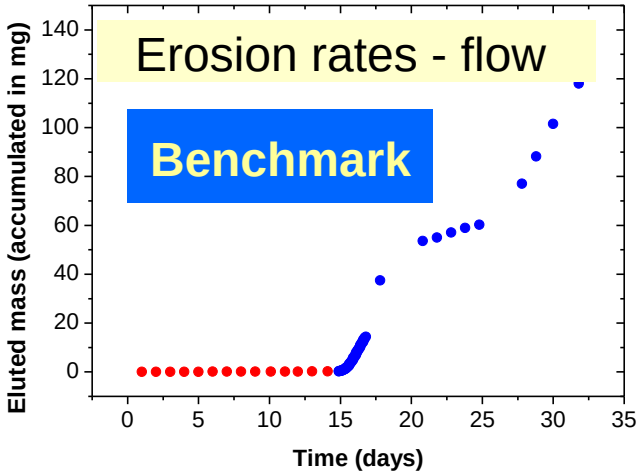
Issue	CIEMAT Outcome
Mechanisms of erosion of clay particles from the Bentonite surface: • **Mechanisms** of clay colloid release (WP2 output). • Improved quantitative models with **new data** (WP5 output).	✓ Clay hydration ✓ Gel like formation ✓ **Favourable conditions** ✓ Extrusion ✓ Mobilisation *(available space)* ✓ **Na-bentonite** (**1.6 g/cm³** in **DW**): 7.3E-2 kg/m²

Extrusion

(chemical dispersion)



Flow 9.5 E-05 m/s
130 ml/day



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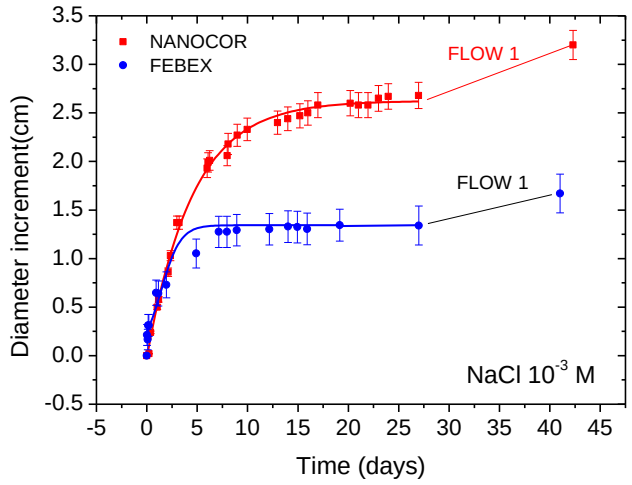
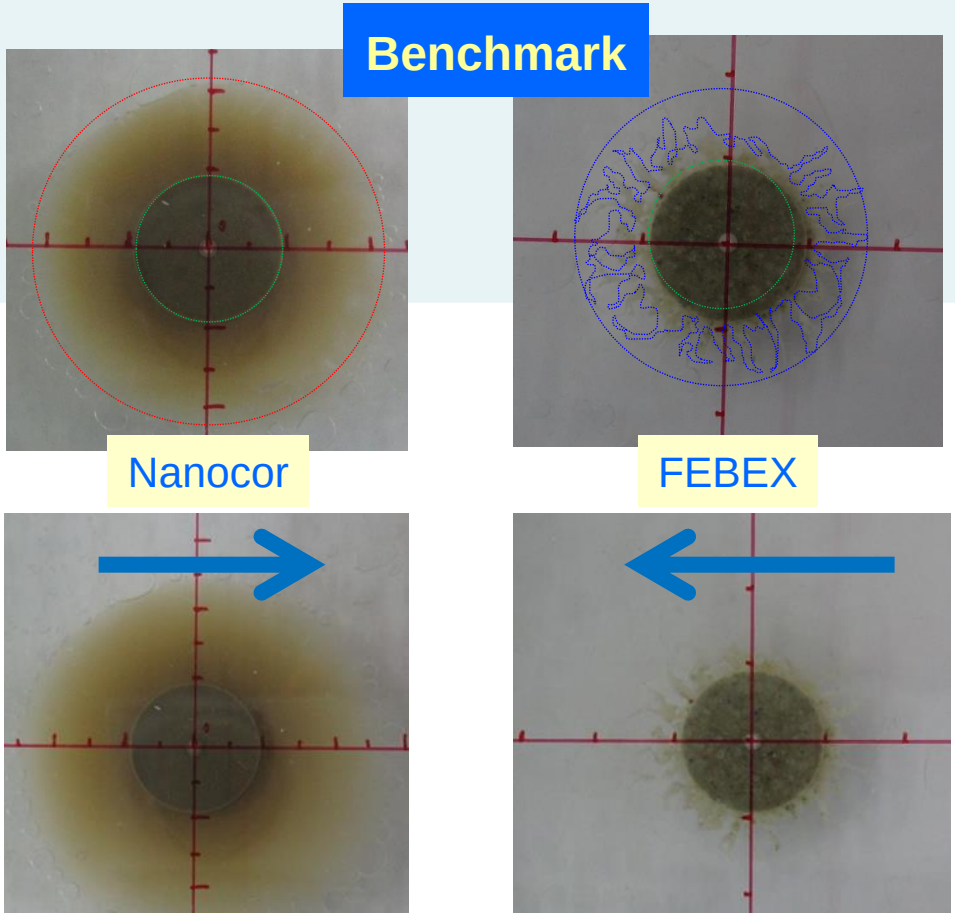
Issue	CIEMAT Outcome
Characteristics of Bentonite clay • The role of divalent cations (WP2 and WP4). • The stability of different bentonites (WP4)	✓ Different clays – different extrusion behaviour.





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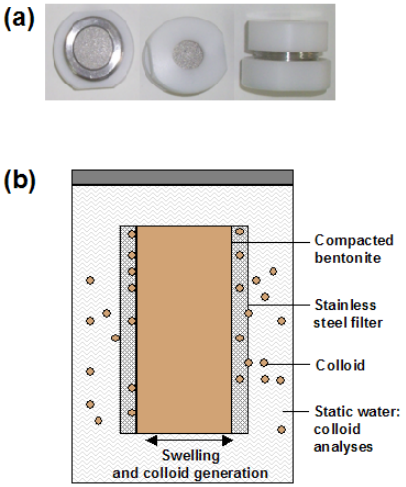
Issue

Characteristics of Bentonite clay

- The role of divalent cations (WP2 and WP4).
- The stability of different bentonites (WP4)

Set-up

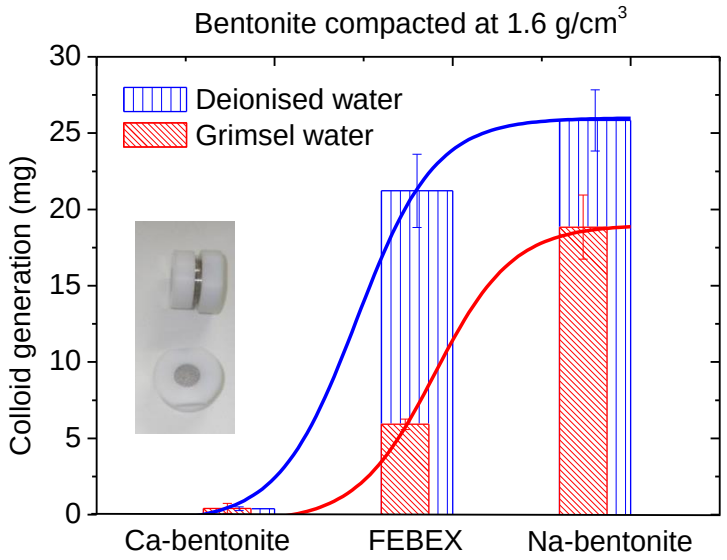


CIEMAT Outcome

✓ Compared erosion behaviour of different bentonites:

- Na- or Ca- homoionic: FEBEX bentonite
- Raw bentonites: MX80, Mylos - G, Rockle B75 -CzR, MSU- Russian, Nanocor
- Mixed clays: Kaolinite, Saponite, Zeolite, Illite, Oxides

Issue	CIEMAT Outcome
Characteristics of Bentonite clay • The **role of divalent cations** (WP2 and WP4). • The stability of different bentonites (WP4)	✓ Dependence on main exchangeable cation of the clay, but not only! ✓ **Ca- bentonite: no erosion** ✓ FEBEX (30% Na): erosion ✓ Relevance of cation exchange (chemistry GW)

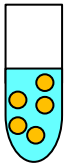


Na-bentonite (**1.6 g/cm³** in **DW**): 7.3E-2 kg/m²

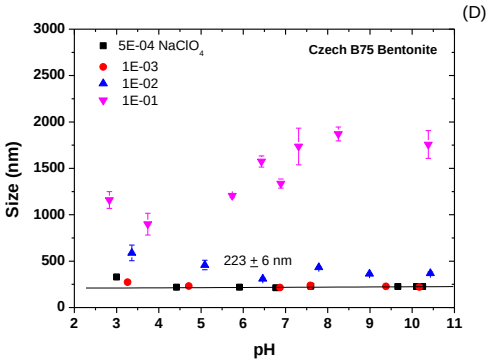
FEBEX 1.6 g/cm³ in DW: 6E-2 kg/m²

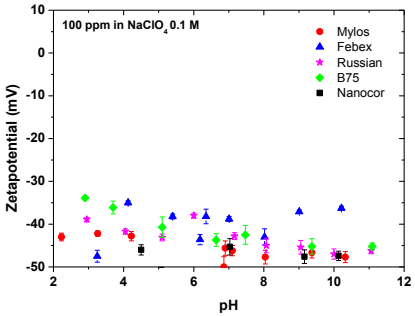
Ca-bentonite 1.6 g/cm³ in DW: 6E-2 kg/m²

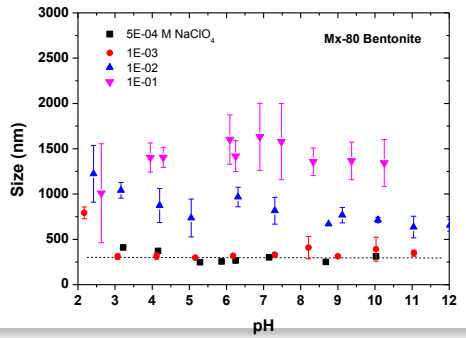
Issue	CIEMAT Outcome
Characteristics of Bentonite clay • The role of divalent cations (WP2 and WP4). • **The stability of different bentonites** (WP4)	✓ When colloids are NOT stable = no erosion. ✓ (WP4) **Analysis of colloid stability (size, charge) does not predict erosion behaviour.**

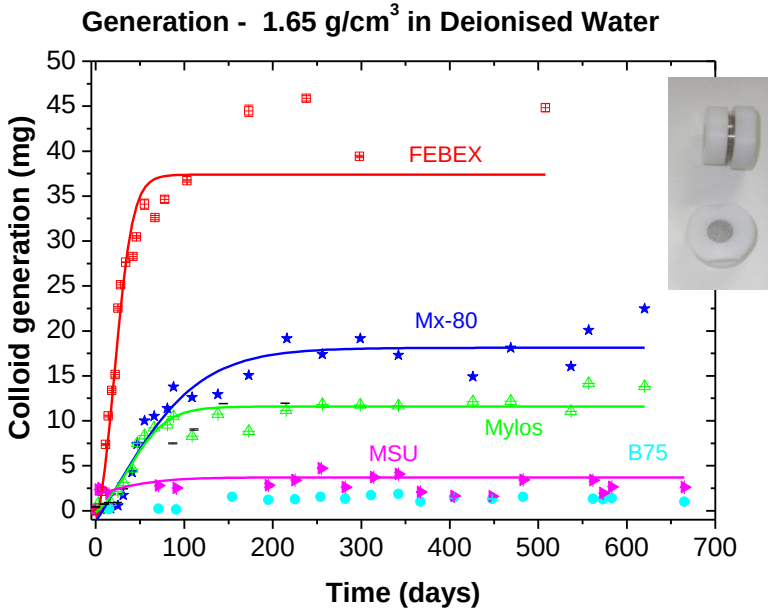


Colloid stability



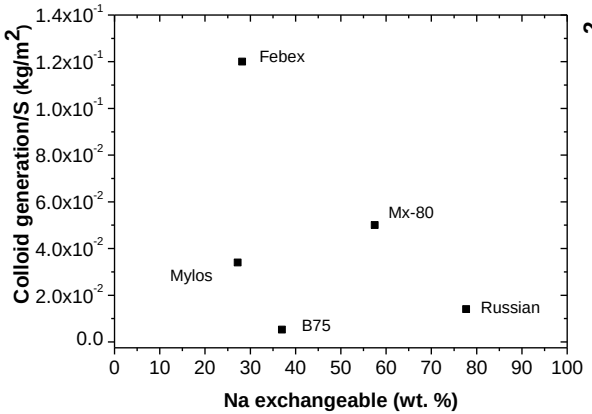




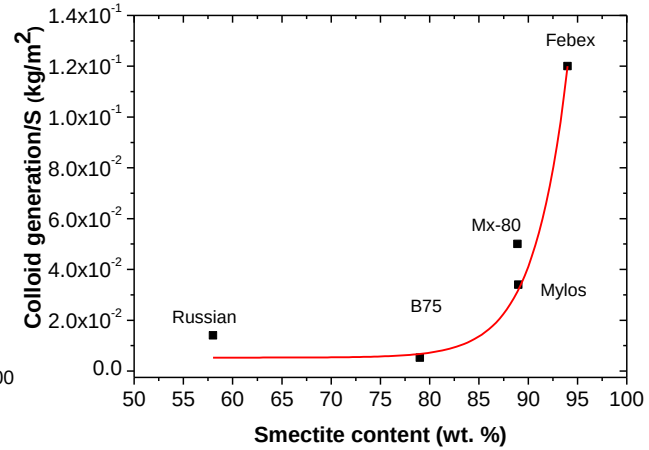


Issue	CIEMAT Outcome
Characteristics of Bentonite clay • The role of divalent cations (WP2 and WP4). • **The stability of different bentonites** (WP4)	✓ Erosion of raw bentonite is not (only) related to the clay exchangeable cations

Exchangeable Na



Smectite content



1.65 g/cm³ DW	Colloid/S (kg/m²)
Febex	$(1.2 \pm 0.5)\cdot10^{-1}$
MX-80	$(5 \pm 0.5)\cdot10^{-2}$
Ibeco	$(3.4 \pm 0.5)\cdot10^{-2}$
Czech B75	$(5.38 \pm 0.5)\cdot10^{-3}$
Khakassia	$(1.13 \pm 0.5)\cdot10^{-2}$

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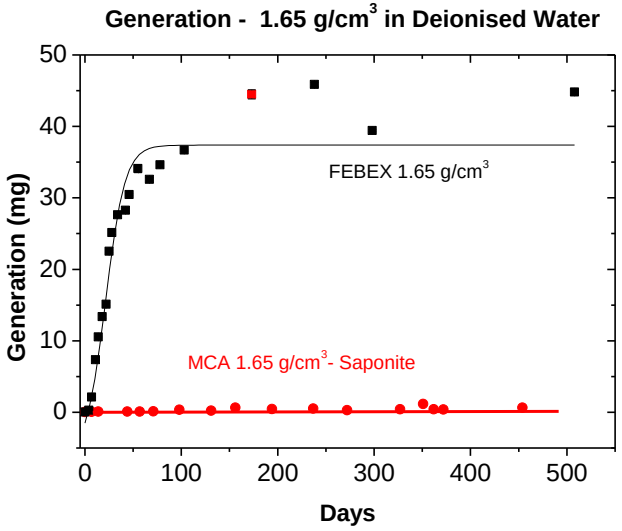
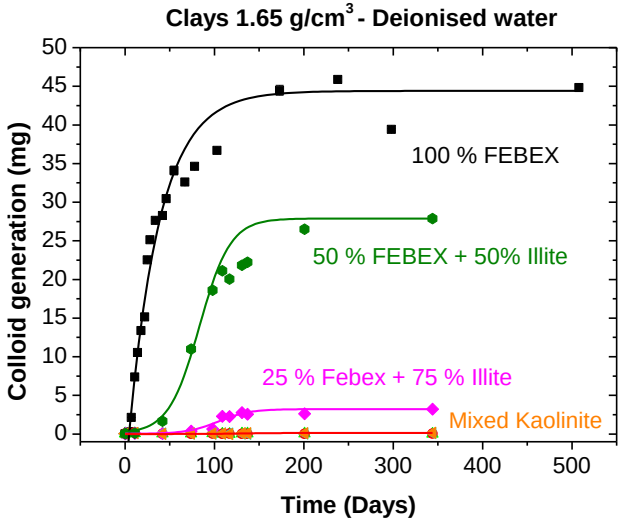
Issue	CIEMAT Outcome
Characteristics of Bentonite clay • The role of divalent cations (WP2 and WP4). • **The stability of different bentonites** (WP4)	✓ Clay compositions and structural characteristics are relevant to define erosion behaviour. ✓ Interpretation of the entire set of (mineralogical) data ongoing.

Swelling clays



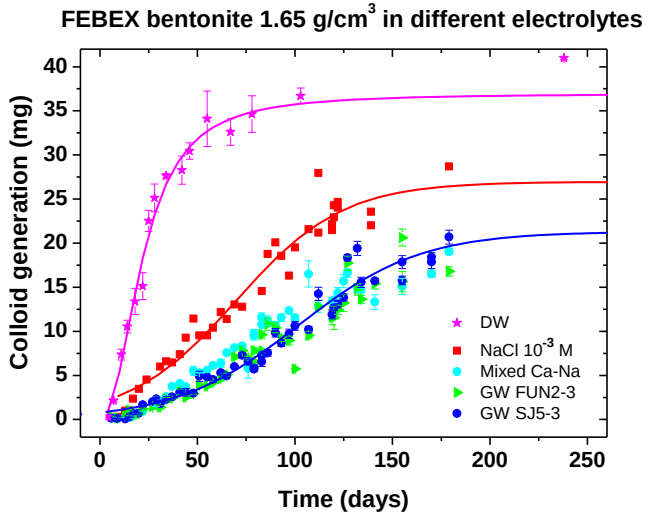
Clay mixtures



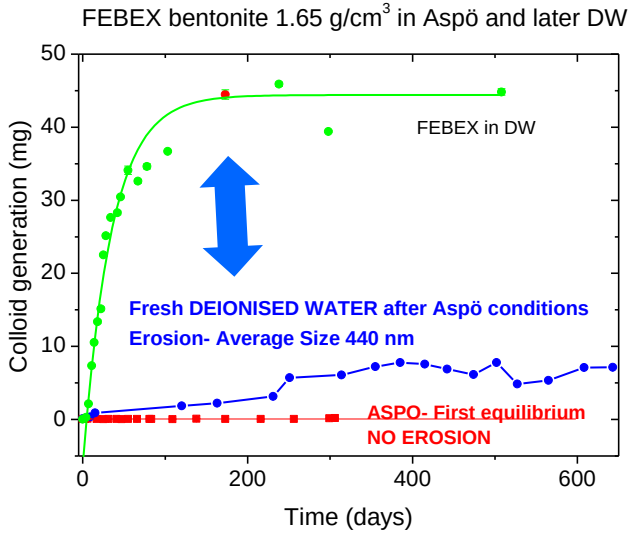
Colloid Stability WP4

Issue	CIEMAT Outcome
Groundwater chemistry • Effect on mixed monovalent/divalent systems (WP2, WP4, WP5).	✓ Ca in groundwater is incorporated to bentonite: inhibits colloid generation. ✓ High relevance of cation exchange processes. ✓ Fresh water income re-launches erosion but to a lower extent. (Hysteresis, stability/reversibility).

FEBEX in "favourable " waters



FEBEX in Äspo



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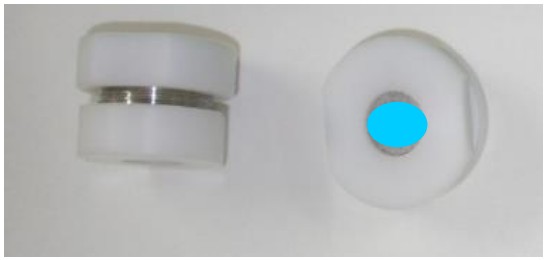
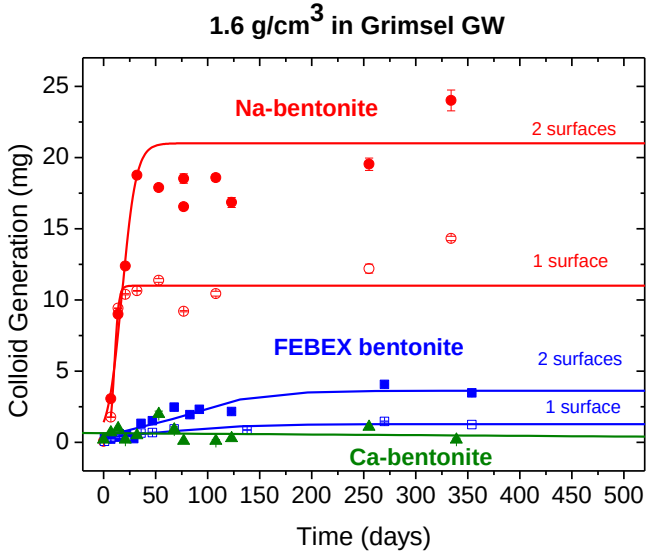
Issue	CIEMAT Outcome
Clay extrusion paths • The effect of fracture geometry on clay mass loss (WP2).	✓ Colloid erosion // mobilisation is limited by the available pore/paths (surface) for transport. ✓ Experimental erosion data should be normalised to extrusion surfaces kg/m^2

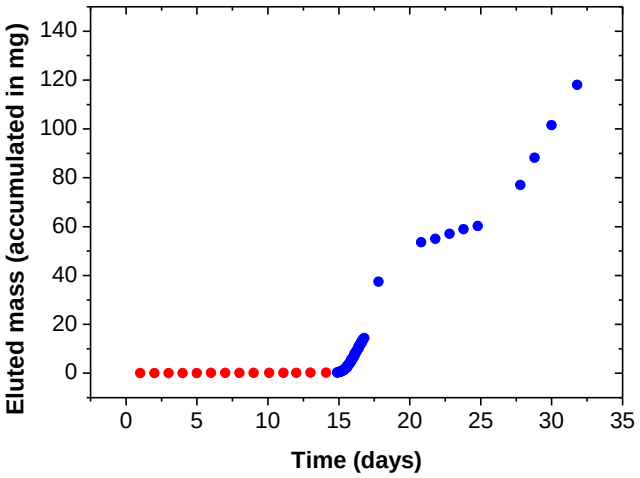


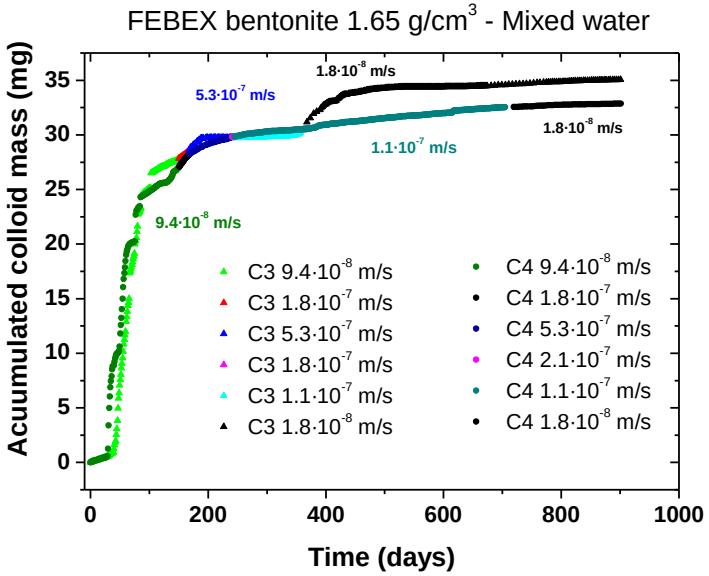


Issue	CIEMAT Outcome
Ground water velocity • Verification of the dependence between the groundwater velocity and the erosion rate.	✓ In Ca - Na electrolytes: Little effect of flow changes (Flow velocities: 10^{-8} - 10^{-7} m/s) ✓ Colloid release clearly slowed down: “equilibrium”

Nanocor- Benchmark

(flow inversion ?





Ca

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Issue

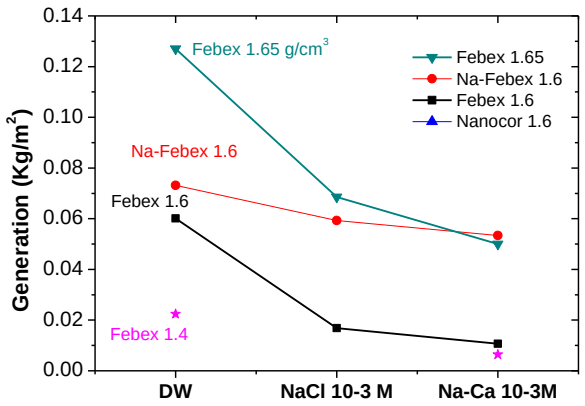
Clay – Groundwater interactions

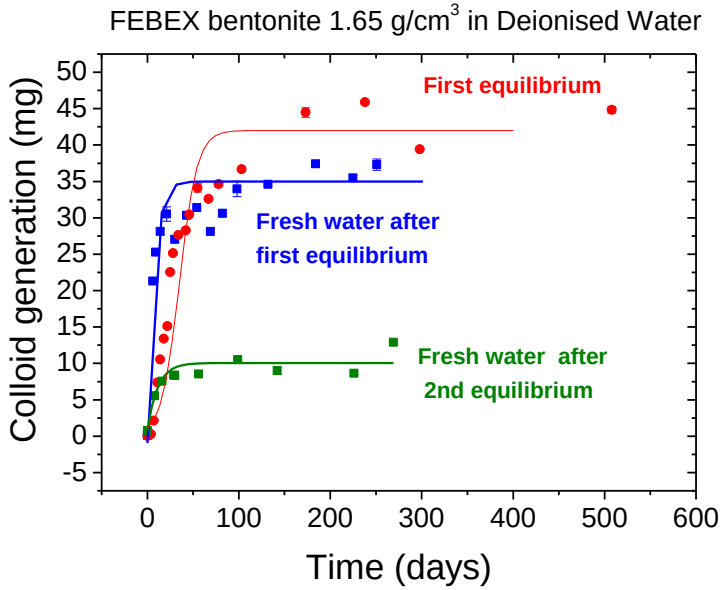
- A validated argumentation for (the conditions for) **maximum clay mass loss rate** to be used in safety case (cross-WP effort).
- *Summary of how these processes should be integrated in the safety case.*

CIEMAT Outcome

✓ Maximum rates form Na-bentonite in deionised water at higher compaction densities (1.6 g/cm^3)

✓ The system tends to an equilibrium





Thanks for your attention