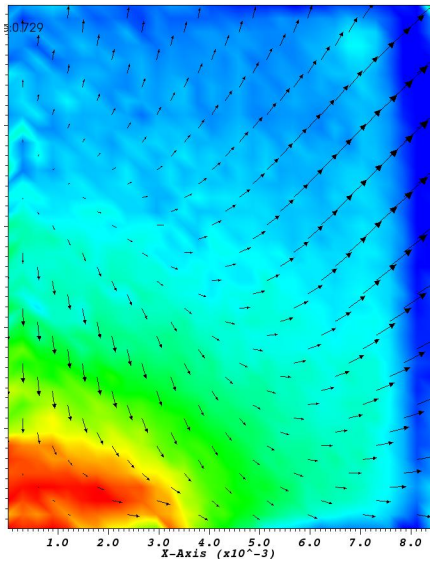

Assessment of Bentonite Characteristics in KB3 Method

19 August 2014, BOA seminar, Espoo

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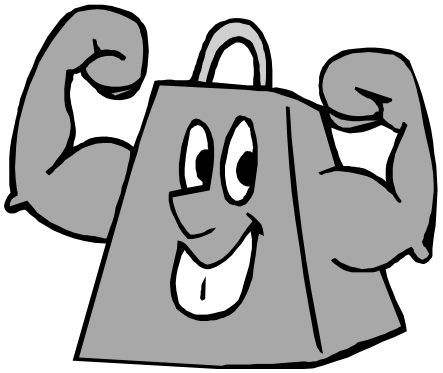
Goals

- THMC(B)-model, sufficiently good over whole parameter space
  - Concept based on experimental observations
  - Needed parameter values and data must be available somehow
  - Mathematical formulation consistent and completed
  - Implementation possible to carry out by present computing methods, tools and resources
- Characterisation and analysis methods, by which all needed determinations can be done
  - Accurate, repeatable and reliable
- Process experiments, which support modelling and vice versa; supported characterisation and analysis methods
  - Carefully selected set of experiments and tests
- NOT a goal: to solve all bentonite issues, but instead to create operations model to study bentonite effectively

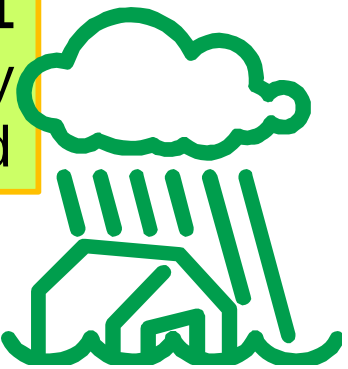
Variation of conditions for bentonite buffer in KBS3 method

Thermodynamic variables

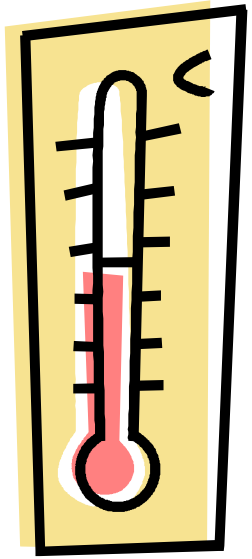
- Temperature, *T*
- Pressure, *P*
- Chemical composition
  - Water, *S*
  - Solid: minerals + exchanged cations, ρ_d
  - Dissolved salts, *I*



S: 0.3…1
Dry - fully saturated



ρ_d: 1…1 700 kg/m³
Montmorillonite + exchanged cations + other accessory minerals



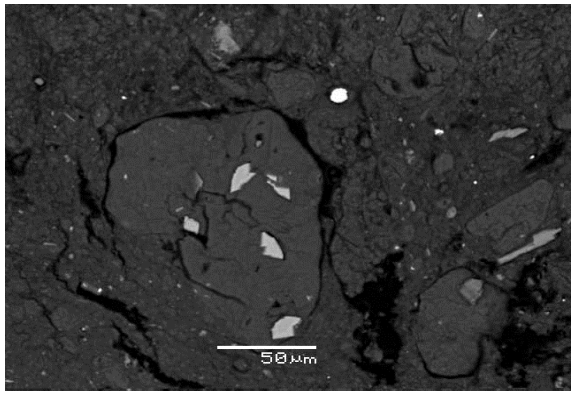
T: -10…100 °C

***P*: 0.1…4 MPa + ice cover**

***I*: 0.01 mM…1 M**
1 mg/L…100 g/L Na-Ca-Cl + other ions, microbes, colloids

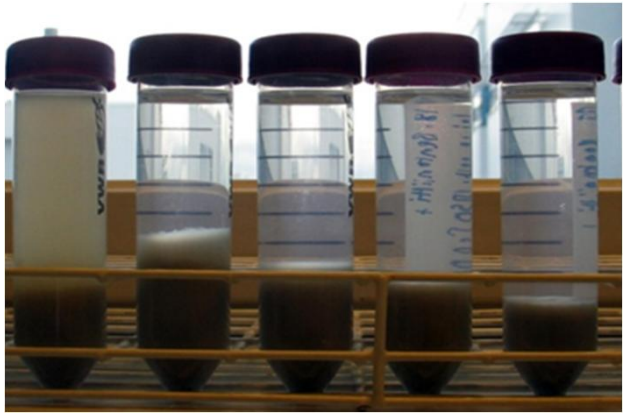
Scales, properties of bentonite and water phase

- **Spatial scales**
  - Colloidal size
  - Pore size
  - Laboratory
  - Small scale
  - Pilot scale
  - Repository scale
- **Time scales**
  - Nanoseconds in molecular dynamics
  - Lab = days to years
  - Repository = years to millenia

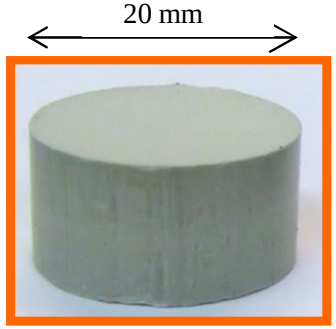


- **Bentonite properties**
  - Relative amount of montmorillonite
  - Cationic form of montmorillonite
  - Accessory minerals
  - Grain size
  - Initial water content
  - “History” of the samples
    - Production
    - Transport
    - Processing

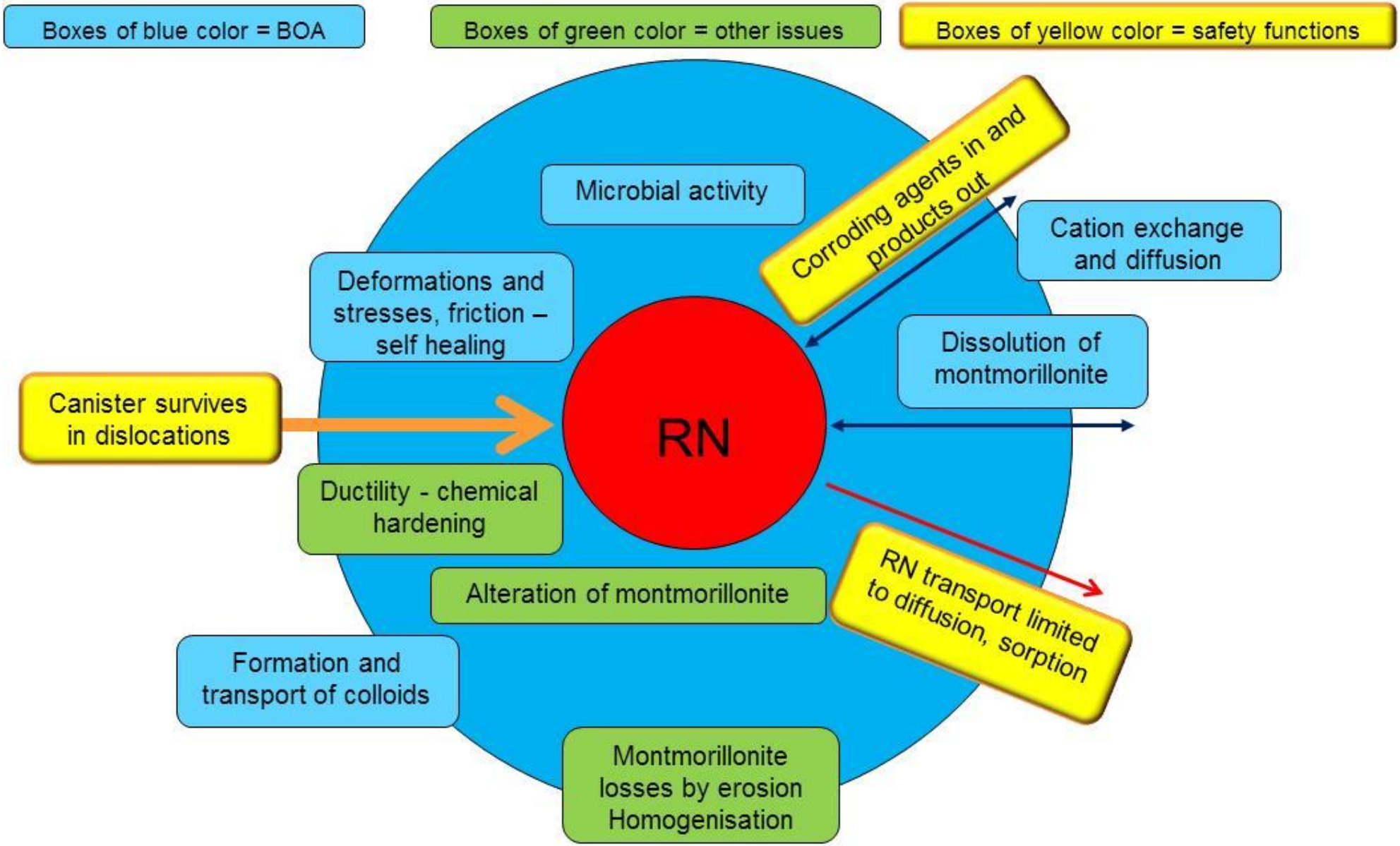
- Water
  - Humidity or saturation
  - Composition
    - Electrolyte
    - Groundwater simulant
  - Gases
  - Colloids
  - Microbes



Compacted bentonite sample

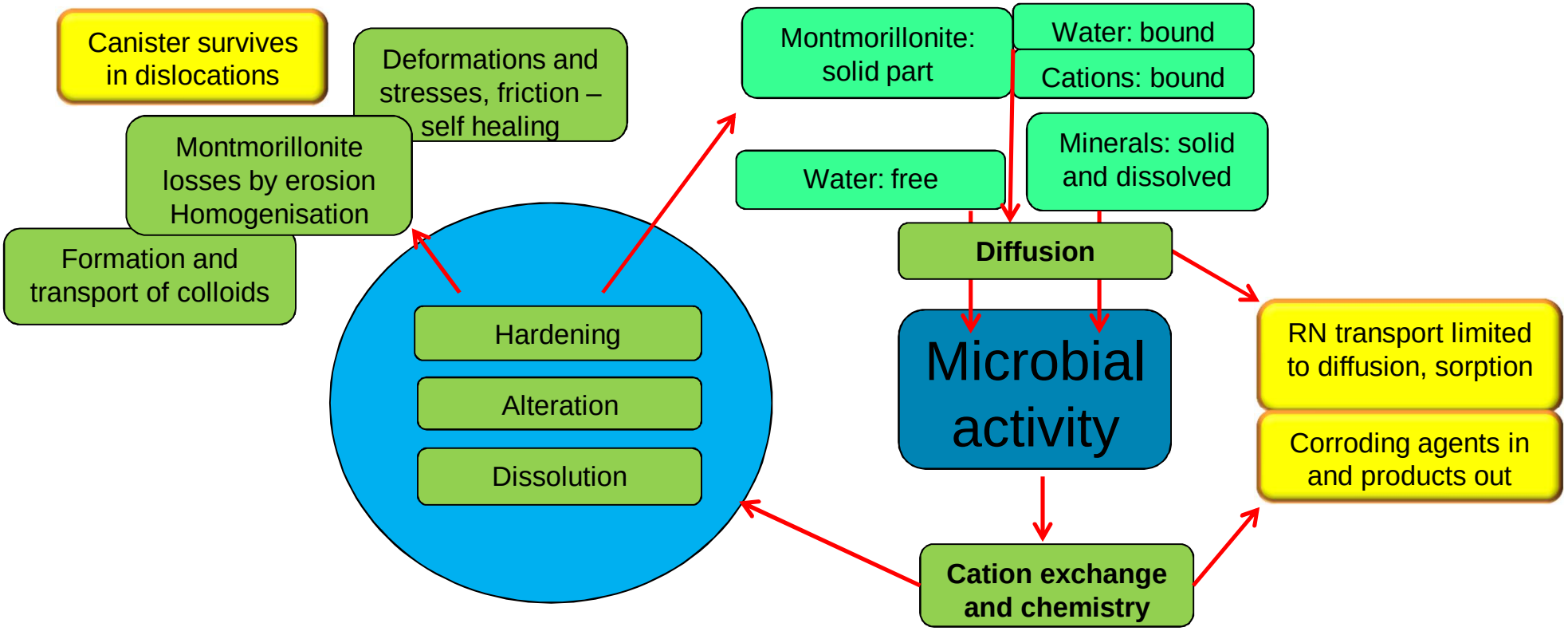


Safety functions (SF): protect canister, and limit and delay release of RN
Processes related to these SFs shown below



Microbes related to processes and structure

Boxes of yellow colour = safety functions

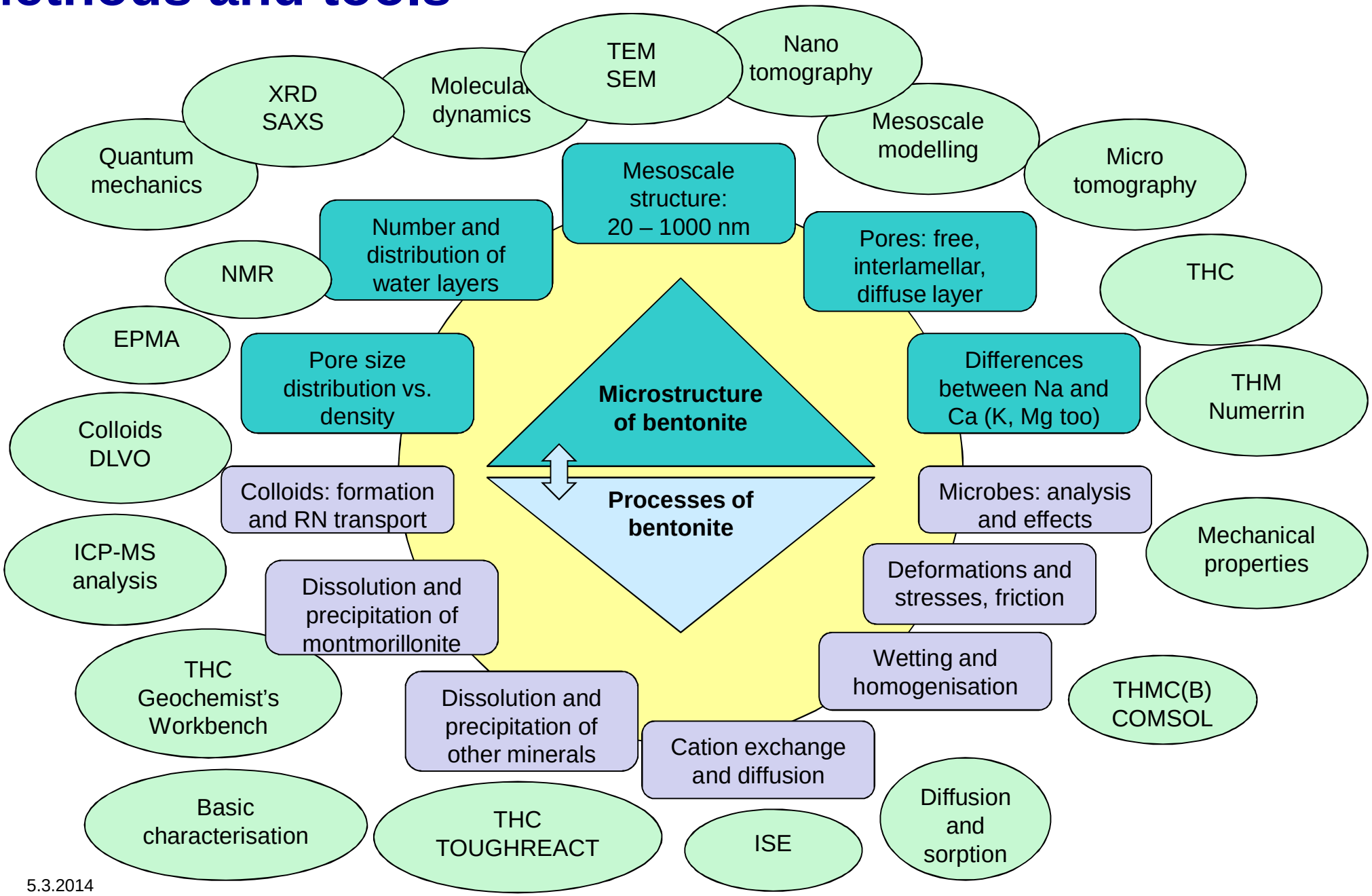


Rock, crushed rock and compacted bentonite

- Buffer material demands: low hydraulic conductivity (*K*), low diffusion conductivity (D_e) and high enough ductility
- Granitic rock: *low K* and D_e, but it is brittle and difficult to apply
- Crushed rock: *high K* and D_e, porosity is high, easy to use
- Bentonite: *low* D_e for anions, acceptable for cations, and very low *K*, and is ductile
- How highly porous bentonite can have all these properties?
- Why the diffusivity values are different for anions and cations?
- Specific microstructure of bentonite: very small pores, interaction of ions with pore surfaces

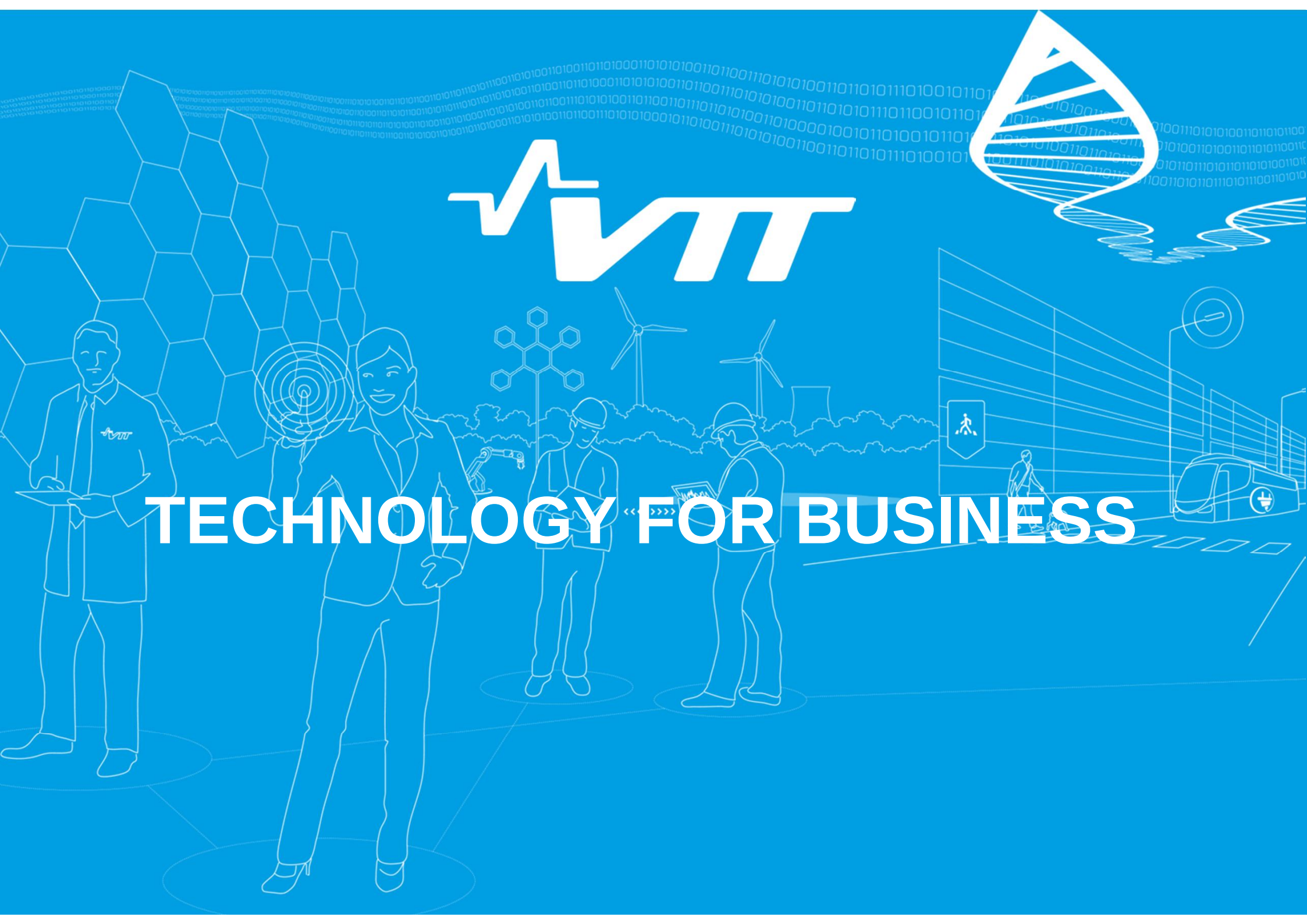
	Dry density (kg/m³)	**Porosity** (-)	**Hydraulic cond. *K* (m/s)**	**D_e anions (m²/s)**	**D_e cations (m²/s)**
rock	2 650	*0.005*	1.00E-09	*1.00E-13*	*1.00E-13*
crushed rock	1 600	0.4	1.00E-04	6.00E-11	6.00E-11
bentonite	1 600	0.4	*1.00E-12*	*2.00E-13*	8.00E-11

Methods and tools



Conclusions

- Still much to study about bentonite in KBS3 method
- New methods are promising and already producing publishable results
- Need of large collaboration between
  - Geologists
  - Physicists
  - Chemists
  - Computer scientists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