Food and Agriculture Organization of the United Nations

GLOSOLAN
GLOBAL SOIL LABORATORY NETWORK

International Network of Salt-Affected Soils

Global and regional overview of calcareous and gypsiferous soils

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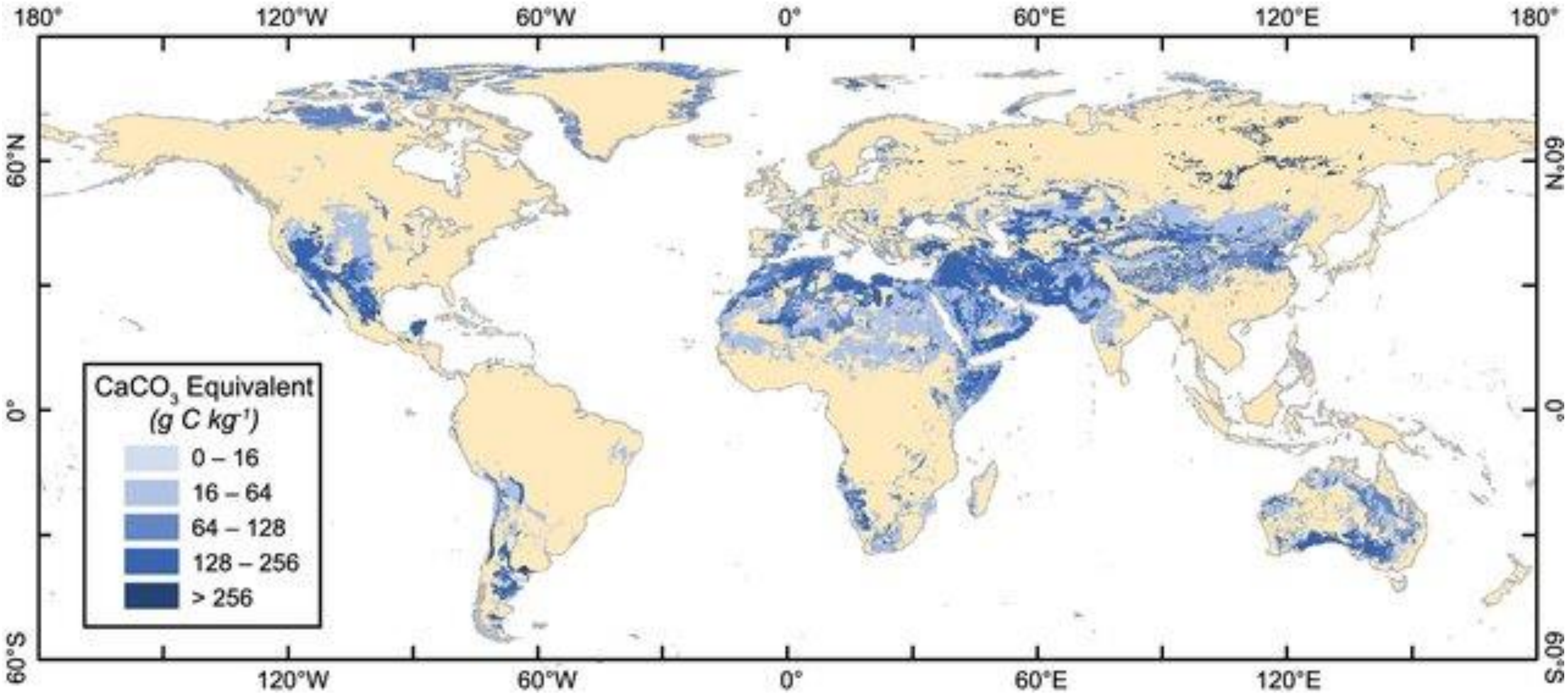
Calcareous soils

- Definition, formation, and distribution
- Analytical and classification challenges
- Agricultural/management implications
- Potential solutions and innovations

Gypsiferous soils

- Definition, formation, and distribution
- Analytical and classification challenges
- Agricultural/management implications
- Potential solutions and innovations

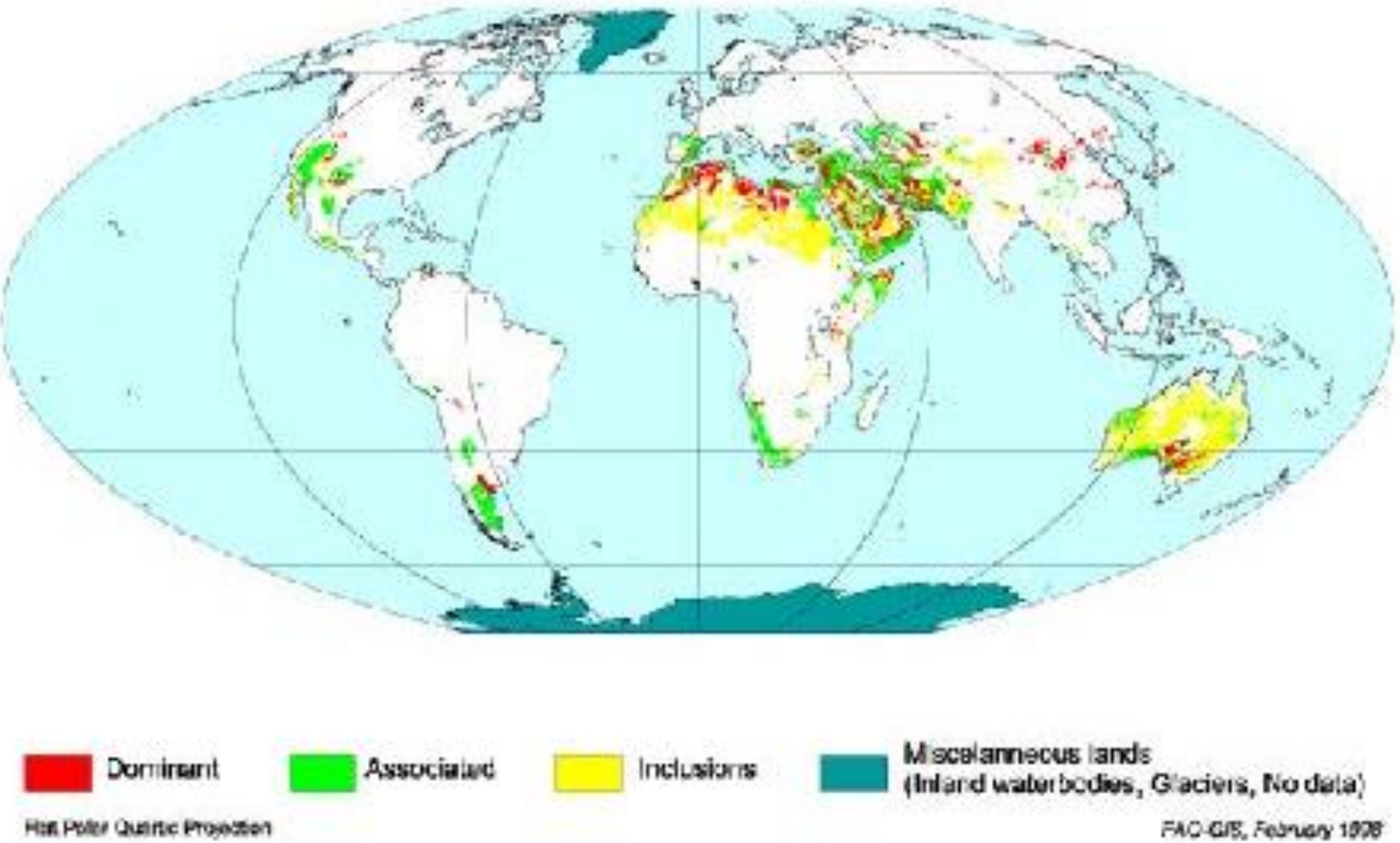
Calcareous soils: definition, formation, distribution



Batjes 2016

Calcareous soils: definition, formation, distribution

Distribution of CALCISOLS
Based on WRB and FAO/UNESCO Soil Map of the World



Calcareous soils: definition, formation, distribution

Calcite ($CaCO_3$) is formed / transported and accumulated *in situ*

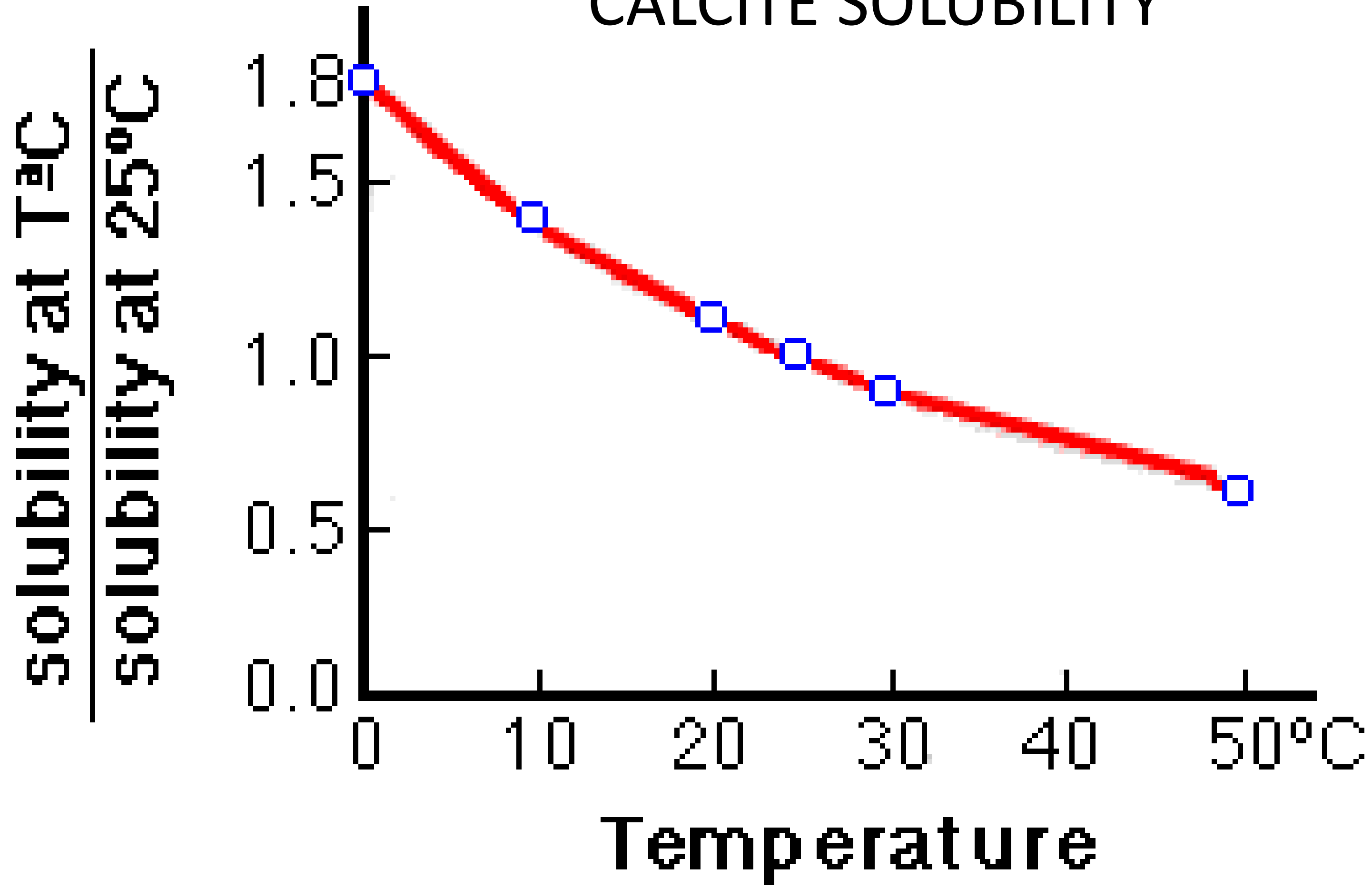
$$2HCO_3^- + Ca^{2+} \rightleftharpoons H_2O + CO_2 + CaCO_3$$

$$\uparrow \qquad\qquad\qquad\qquad \uparrow$$

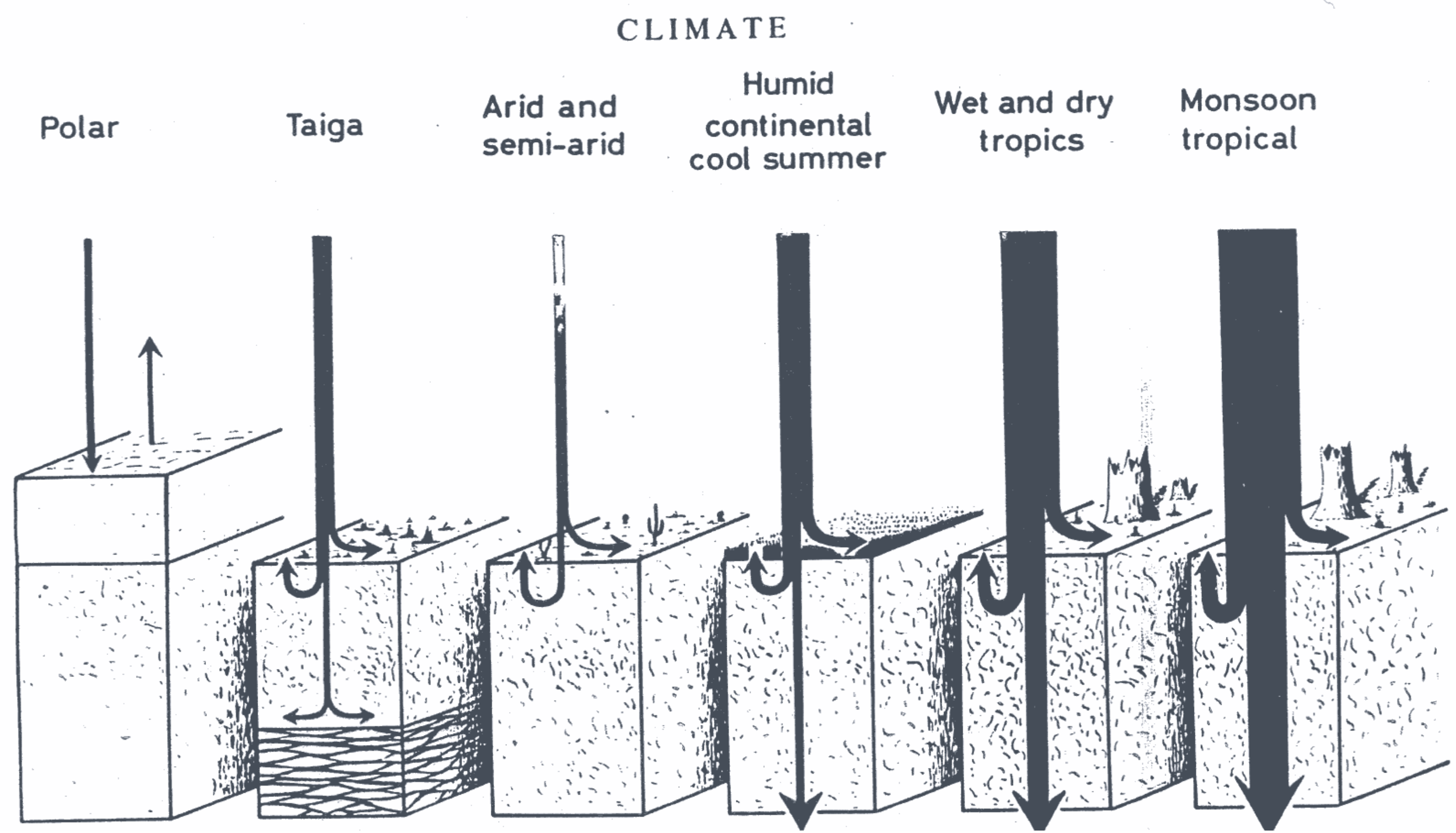
$$HCO_3^- + H^+ \rightleftharpoons H_2O + CO_2$$

- Influence of biological activity
- In warm areas with limited precipitation: 400 - 600 mm
- Soil moisture regimes (USDA): aridic, xeric, ustic
- Solubility: 5-6 mg/l
- pH buffered between 7.5-8.5
- Well developed soil structures
- Field detection with HCl 11% $CaCO_3 + 2HCl \rightarrow CO_2 + CaCl_2 + H_2O$

CALCITE SOLUBILITY



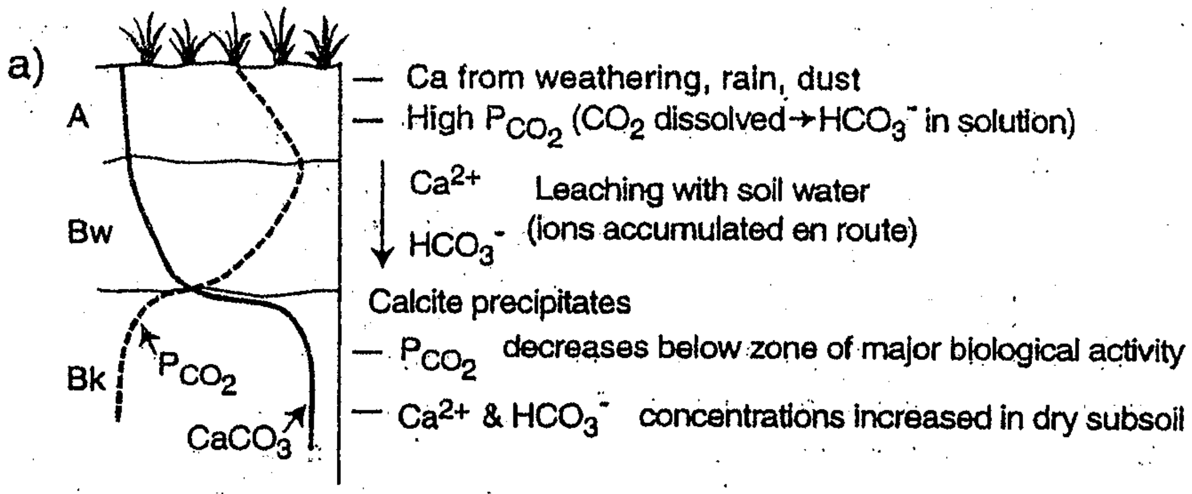
Calcareous soils: definition, formation, distribution



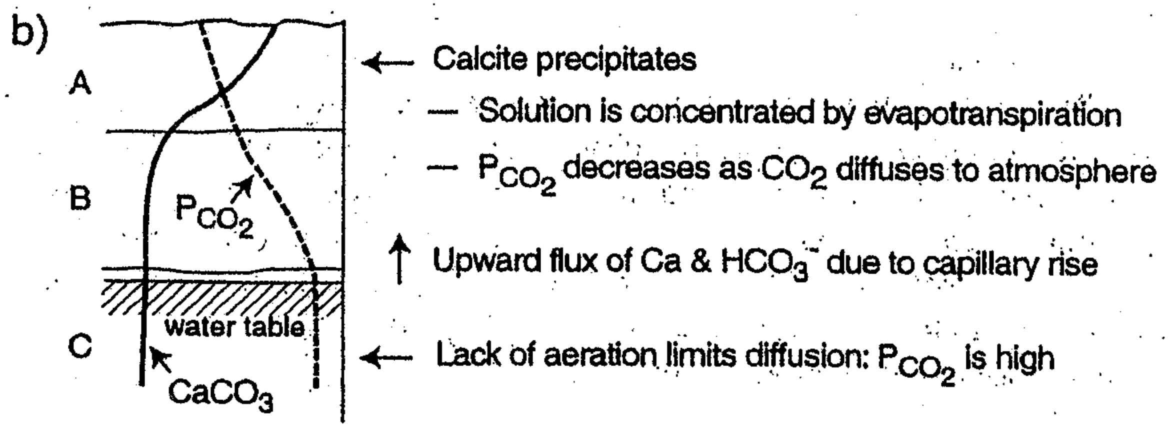
FitzPatrick, 1993

In situ model

Vertical leaching of the surface horizons: descending water during the course of pedogenesis



Vertical ascensum by capilary rise: upward water movement from a groundwater



(Chadwick & Graham, 2000)

Calcareous soils: definition, formation, distribution

DISSOLUTION OF LIMESTONE

KARREN

(lapiaz, rascler, lenar,…)

Calcareous soils: definition, formation, distribution

HORIZONS WITH CARBONATE ACCUMULATIONS (WRB and USDA):

CALCIC HORIZONS: non cemented (Bk, Bkc)

A diffuse accumulation with or without pseudomycelia

Horizon with friable accumulations

Horizon with nodules / rhyzocretions

PETROCALCIC HORIZONS: cemented (Bkm)

Calcareous soils: definition, formation, distribution

PSEUDOMYCELIA

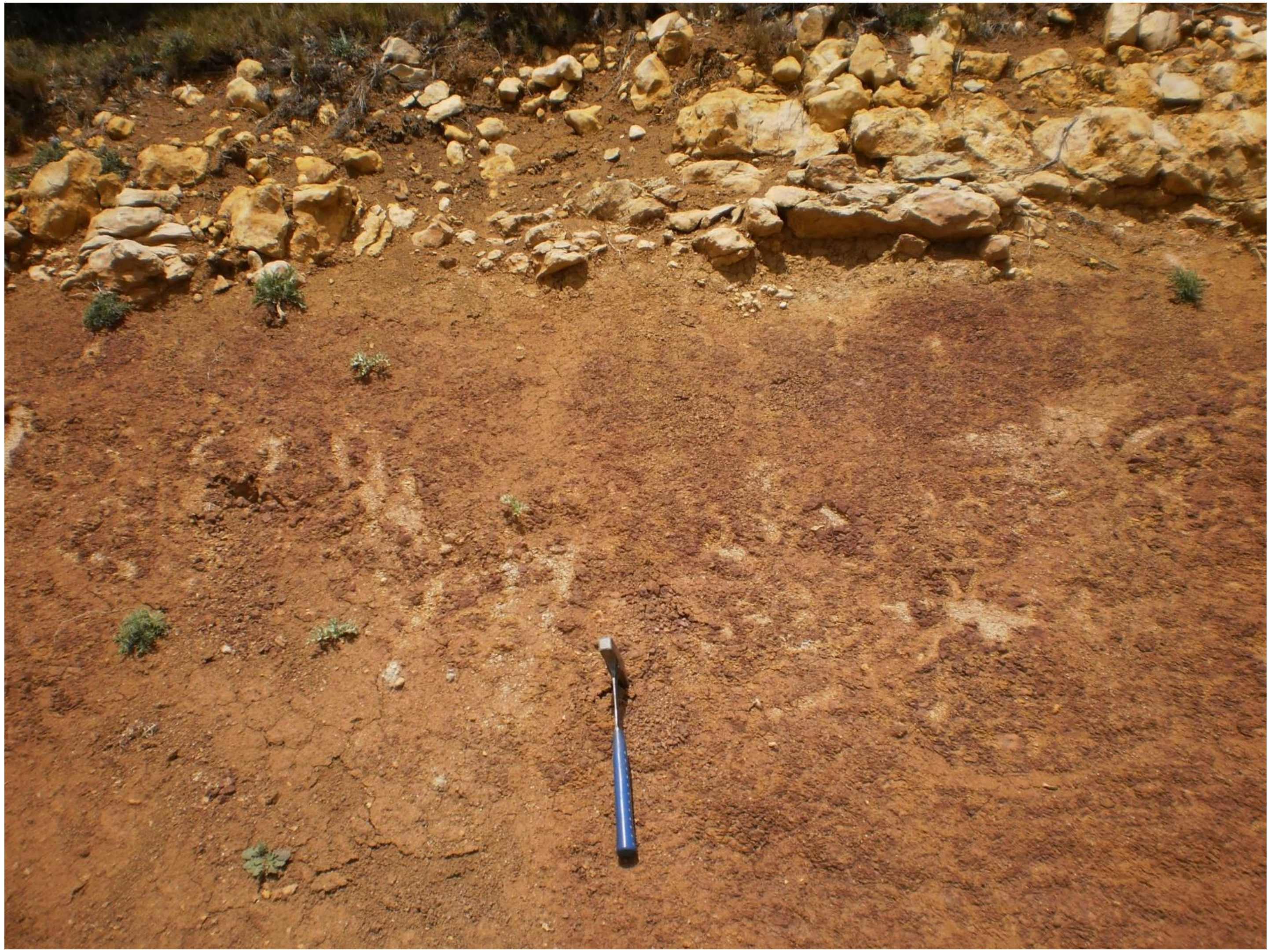
Calcareous soils: definition, formation, distribution

CARBONATE NODULES (RHYZOCRETIONS)

Bkc horizon

Calcareous soils: definition, formation, distribution

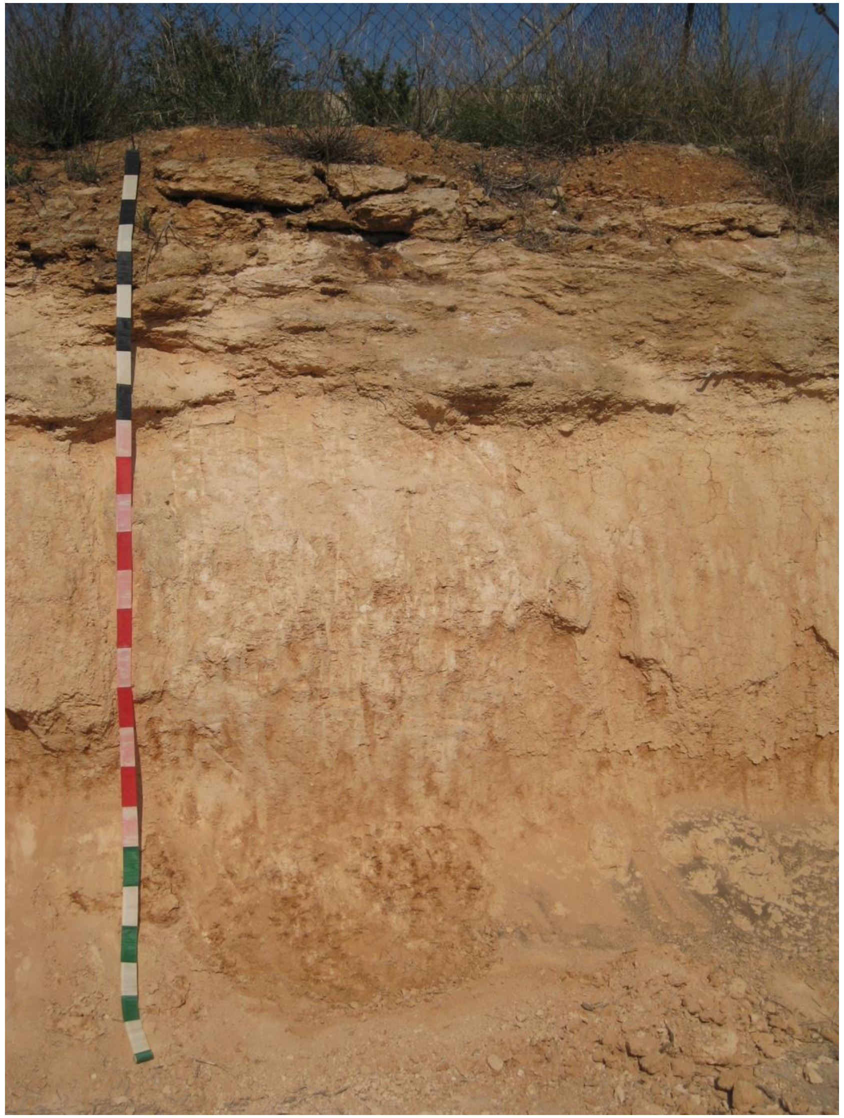
SOFT
CARBONATE
NODULES



CARBONATE PENDENTS

Bk horizon

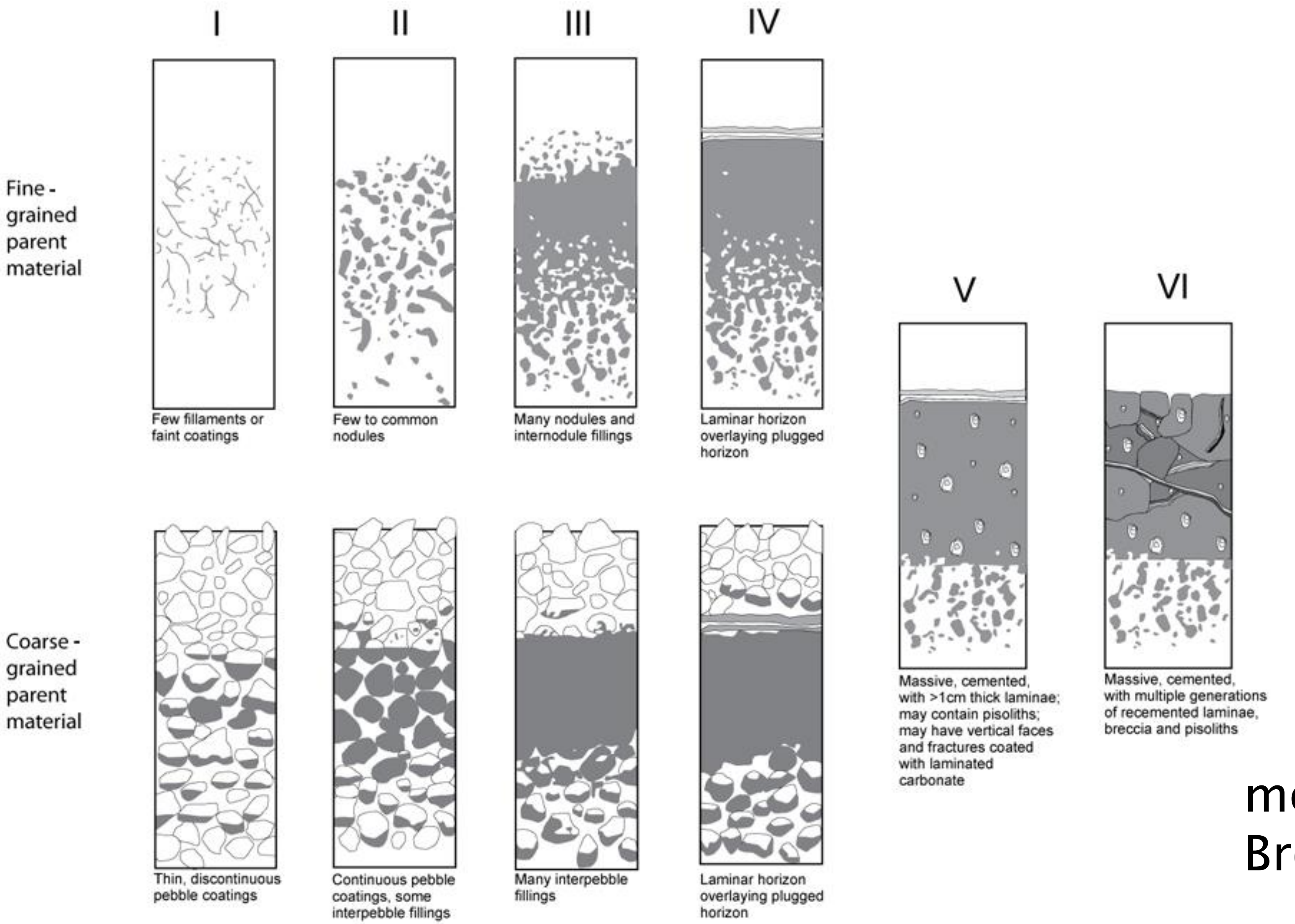
Calcareous soils: definition, formation, distribution



CARBONATE CEMENTATION: slacking tests

Bkm horizon

Calcareous soils: definition, formation, distribution



mod. Machette stadials, Brock, 2007

Calcareous soils: agricultural, management implications

Iron chlorosis

- Fe-deficiency due to precipitation as Fe-carbonate.
- With sensitive crops it is necessary to apply Fe as chelates through the soil or leaves.
- Use chlorosis-resistant cultivars

Calcareous soils: agricultural, management implications

Phosphorous retrogradation

- P – defficiency due to precipitation as $Ca_3(PO_4)_2$
- Use of superphosphate fertilizer (higher solubility)

Calcareous soils: agricultural, management implications

Physical constraints

Cemented Bkm horizons
Ploughing yes or not?

Calcareous soils: analytical and classification challenges

DIAGNOSTICS
Calcic, Petrocalcic horizons
Calcaric material (WRB)

SOILS
Soil Taxonomy (examples)

Order	Suborder
Aridisols	Calcids
Inceptisòls	Calcixerepts
Mollisols	Calcixerolls

WRB:
Calcisols, Calcaric qualifier in other RSG

Calcareous soils: analytical and classification challenges

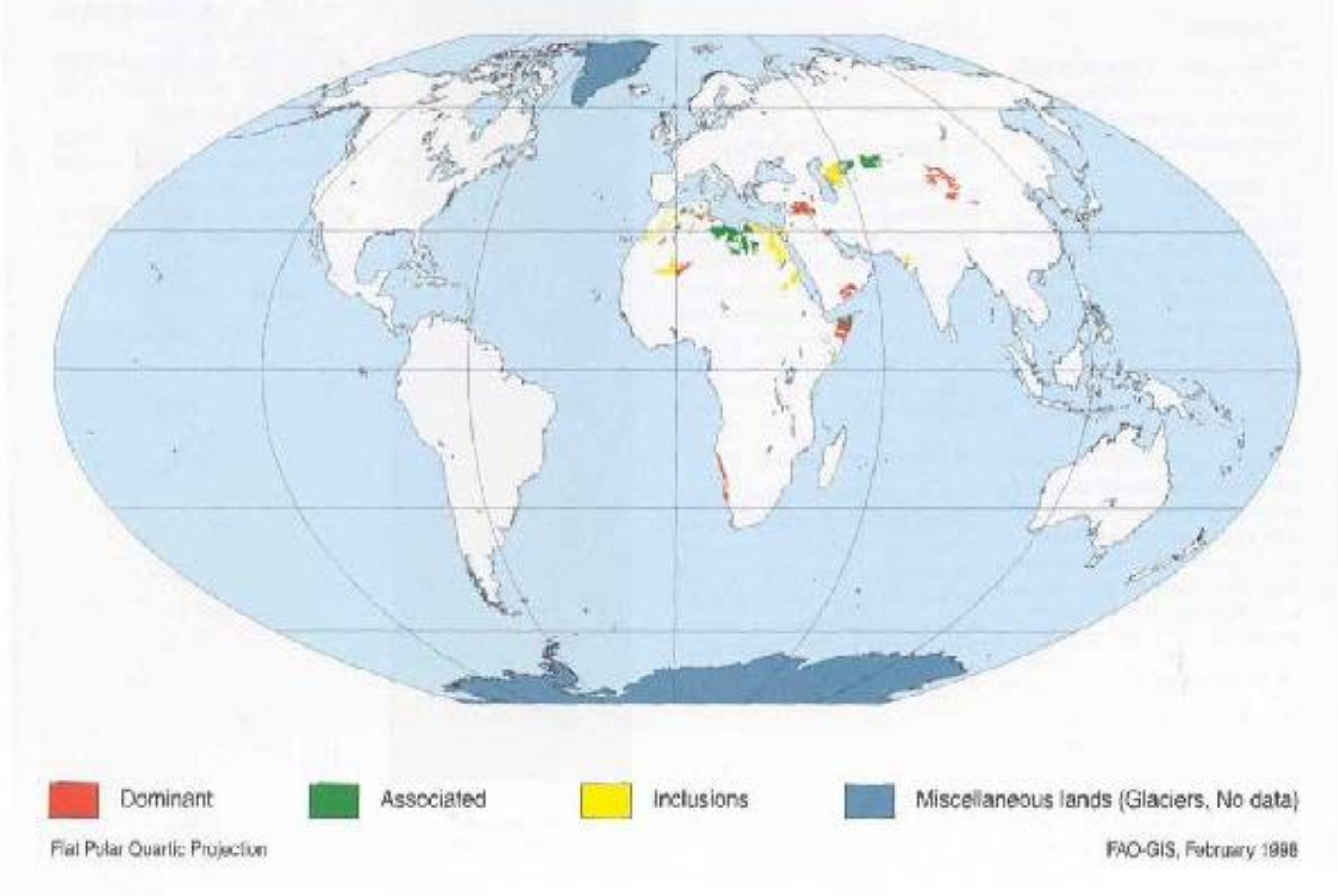
- Calcium Carbonate Equivalent (CCE):
  - Amount of carbonates released with HCl 50% (either $CaCO_3$ or $MgCO_3$) expressed as Calcium Carbonate
  - Bernard Calcimeter.

- Active Lime: fraction of $CaCO_3$ < 50 µm.
  - High reactivity, dissolves easily in soil water containing dissolved carbon dioxide (CO_2).
  - Fine fraction of $CaCO_3$ that reacts with a solution of ammonium oxalate $(NH_4)_2C_2O_4$ (Drouineau, Drouineau-Galet or Nijelsohn methods).
  - If >10 %, problems may appear.

- Textures: Do not remove carbonates! Add more Na-hexametaphosphate
- Extractable cations when analyzing CEC: calculate Ca by substraction.

Gypsiferous soils: definition, formation, distribution

Distribution of Gypsisols



Gypsiferous soils: definition, formation, distribution

	solubility
Calcite: $CaCO_3$	5 - 6 mg/l
Gypsum: $CaSO_4.2H_2O$	**2.6 g/l**
Halite: NaCl	40 g/l

EC_e : 2.2 dS m^{-1} 25ºC

Soils with gypsum ARE NOT SALINE

$$\mathbf{CaSO_4.2H_2O} \xrightarrow{\text{50-70ºC}} \mathbf{CaSO_4.1/2H_2O} + 3/2\ H_2O$$

gypsum → bassanite

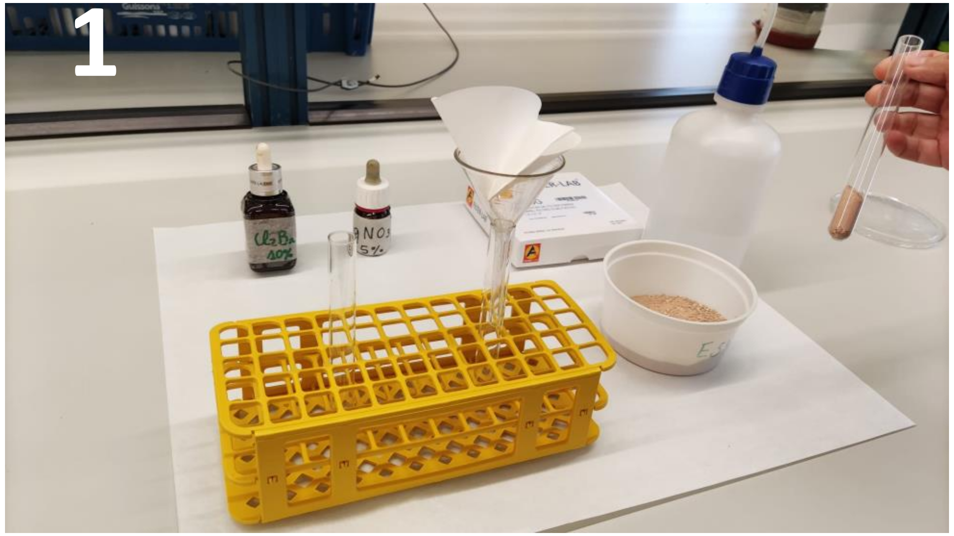
$$\mathbf{CaSO_4.1/2H_2O} \xrightarrow{\text{150ºC}} \mathbf{CaSO_4} + 1/2\ H_2O$$

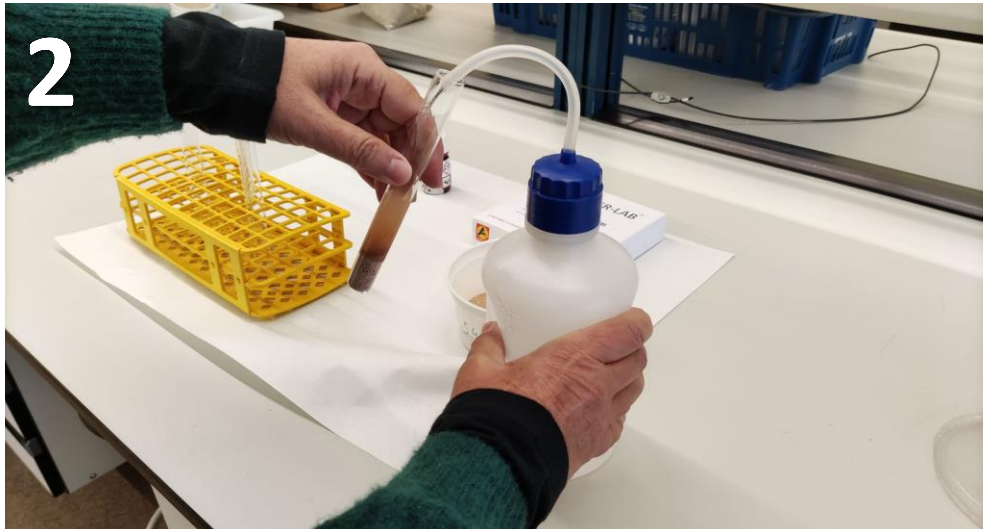
bassanitE → anhydrite

Gypsiferous soils: definition, formation, distribution

CHLORIDES $AgNO_3$ *(5%)* + Cl^- → $AgCl$ ↓

SULPHATES $BaCl_2$ *(10%)* + SO_4^{2-} → $BaSO_4$ ↓

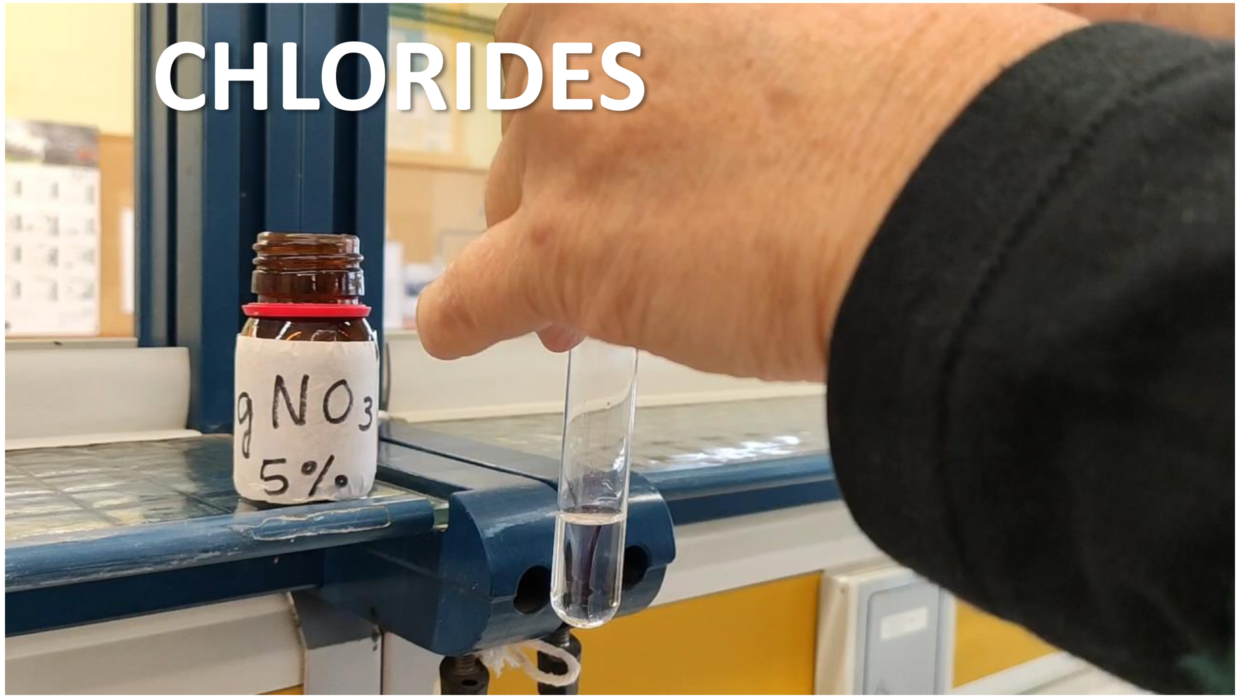




FIELD TESTS

$AgNO_3$ *(5%)* + $Cl^- \rightarrow AgCl \downarrow$

$BaCl_2$ *(10%)* + $SO_4^{2-} \rightarrow BaSO_4 \downarrow$



M Antúnez

Origin of gypsum

- Evaporites (Tertiary, Quaternary)
- Groundwater
- Wind-blown

- Acid-sulphate soils

Gypsiferous soils: definition, formation, distribution

Gypsiferous soils: definition, formation, distribution

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Gypsiferous soils: definition, formation, distribution

Polygonal gypsum crusts

Surface gypsum accumulation, massive, prismatic structure, polygonal surface pattern in horizontal sections. Polygonal plates with upturned edges.

G Stoops

Vermiform gypsum

Fine, undulating tubes or nodules, lower chroma and higher value than the soil matrix, consistency from soft to firm.

By horizon

Gypsiferous soils: definition, formation, distribution

By horizons

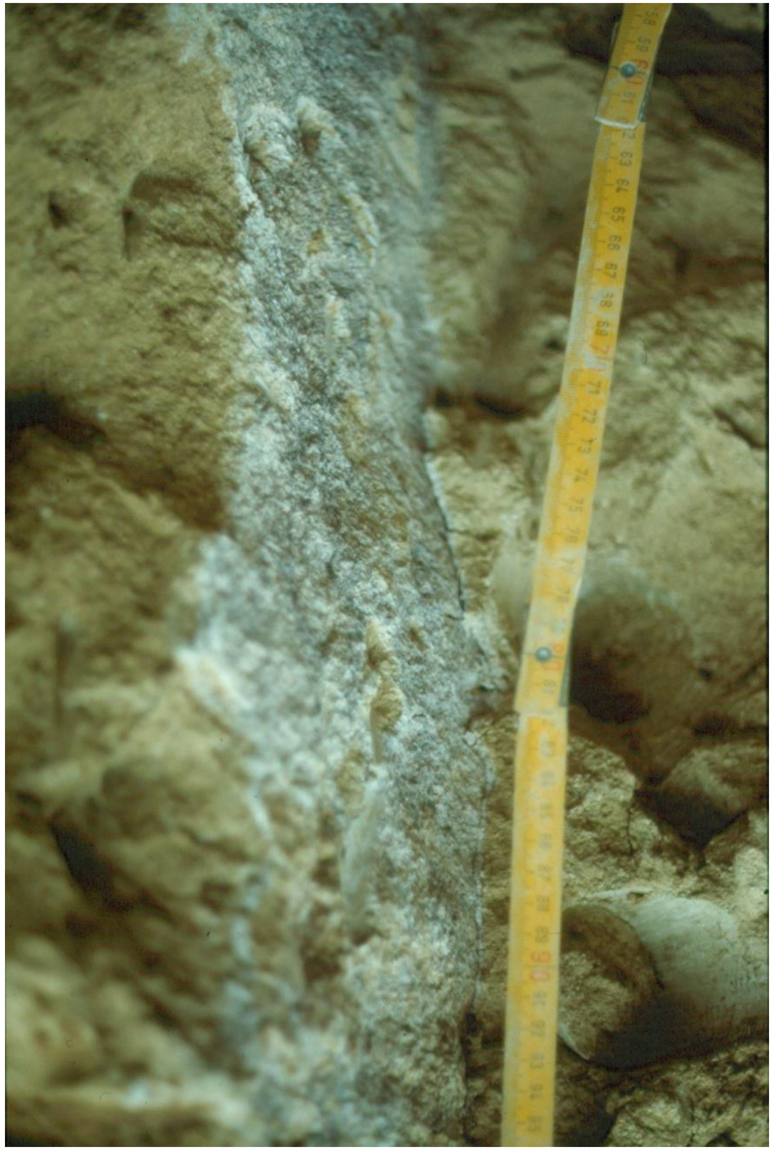
GYPSUM PENDENT

GYPSUM ROSES

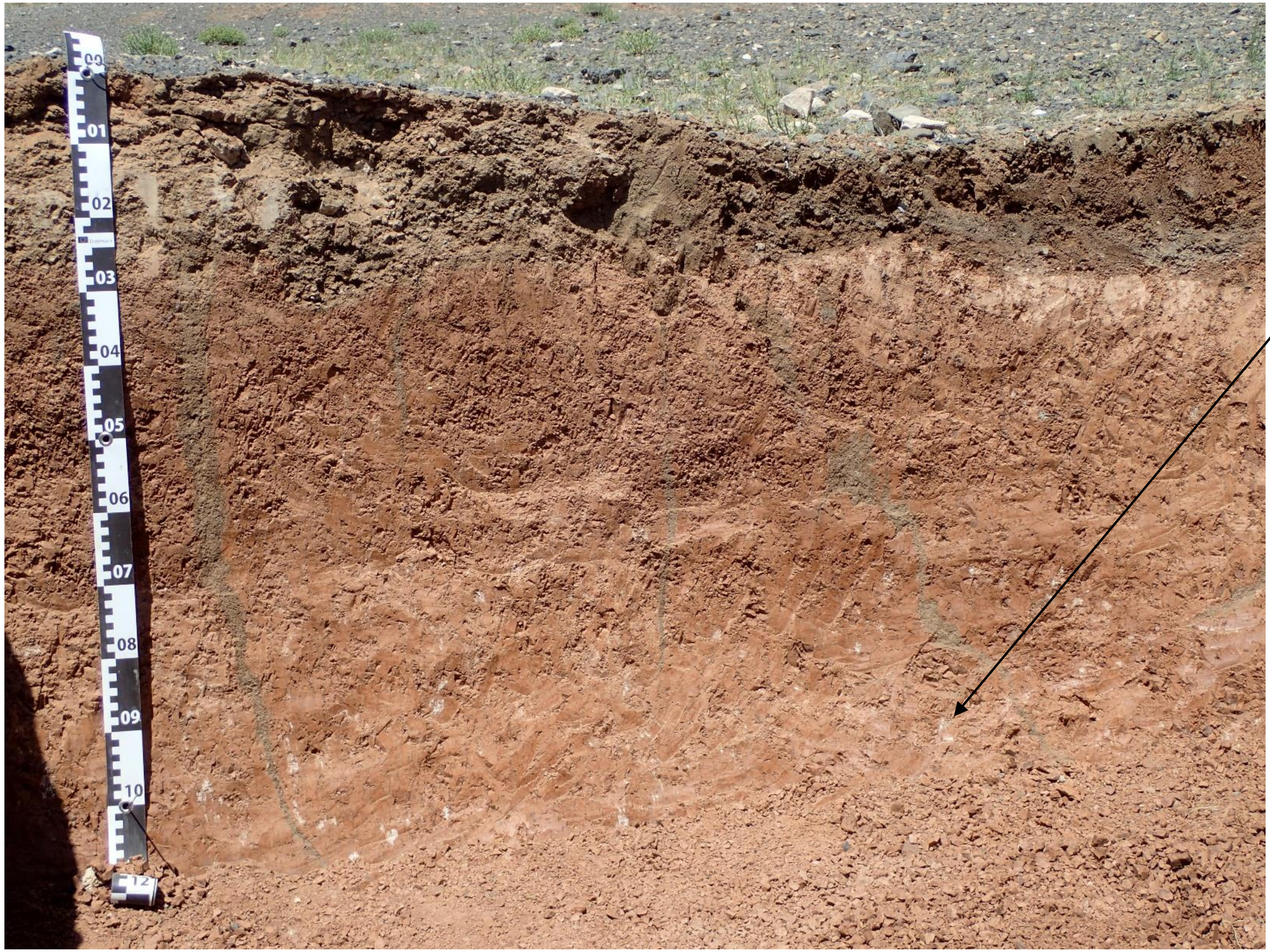
Gypsiferous soils: definition, formation, distribution

By horizons

GYPSUM COATINGS ON CRACKS



Gypsiferous soils: definition, formation, distribution



FIBROUS GYPSUM

Gypsiferous soils: definition, formation, distribution

Reducing environments

Formation of pyrite FeS_2

<u>Acid sulphate soils</u>

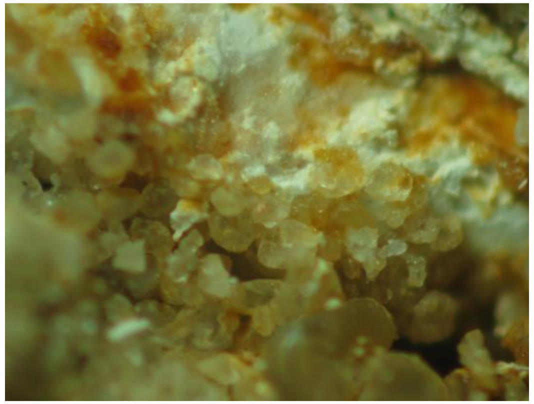
↓

oxidation

with $CaCO_3$

↓

Gypsum $CaSO_4 2H_2O$

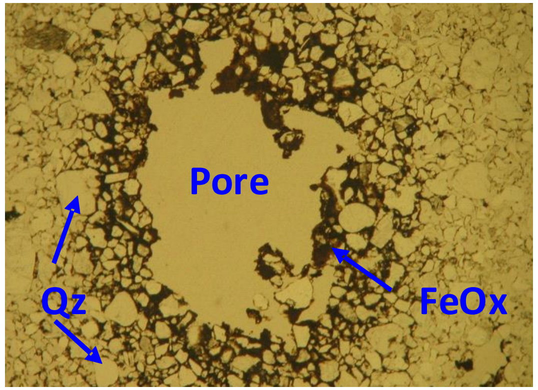


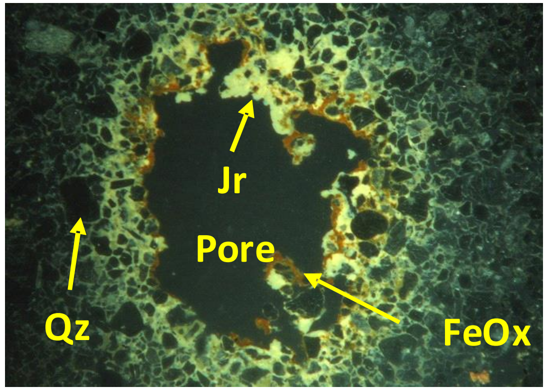
Without $CaCO_3$

↓

Very low pH

Jarosite $KFe_3(SO_4)_2(OH)_6$





Flour-like gypsum

Massive accumulation of gypsum (80-95%, *hypergypsic*), friable, flour-like, silty texture.

By horizons

Gypsiferous soils: definition, formation, distribution

Bym horizons

Test: collapsing or not with water, qualifies for petrogypsic already if weakly cemented GYPSUM IS SOFT!!

Gypsiferous soils: agricultural, management implications

Chemical fertility

P retrogradation (precipitation of calcium phosphate)

Antagonisms with other cations (B deficiency)

Structural stability

low gypsum content: Ca^{2+} improves structure

high gypsum content: weak cohesive forces, poor aggregation, erosion, mud flows.

Dissolution and recrystallization

pore clogging: higher compacity

crusting

Water holding capacity

lower as gypsum increases (sandy horizons)

Hydraulic conductivity

Not affected (generally)

Corrosion of concrete

formation of etringate (calcium aluminium sulphate·31 H_2O)

maintenance of structures

Karstification

Gypsiferous soils: agricultural, management implications

Gypsiferous soils: agricultural, management implications

Karstification

Gypsiferous soils: agricultural, management implications

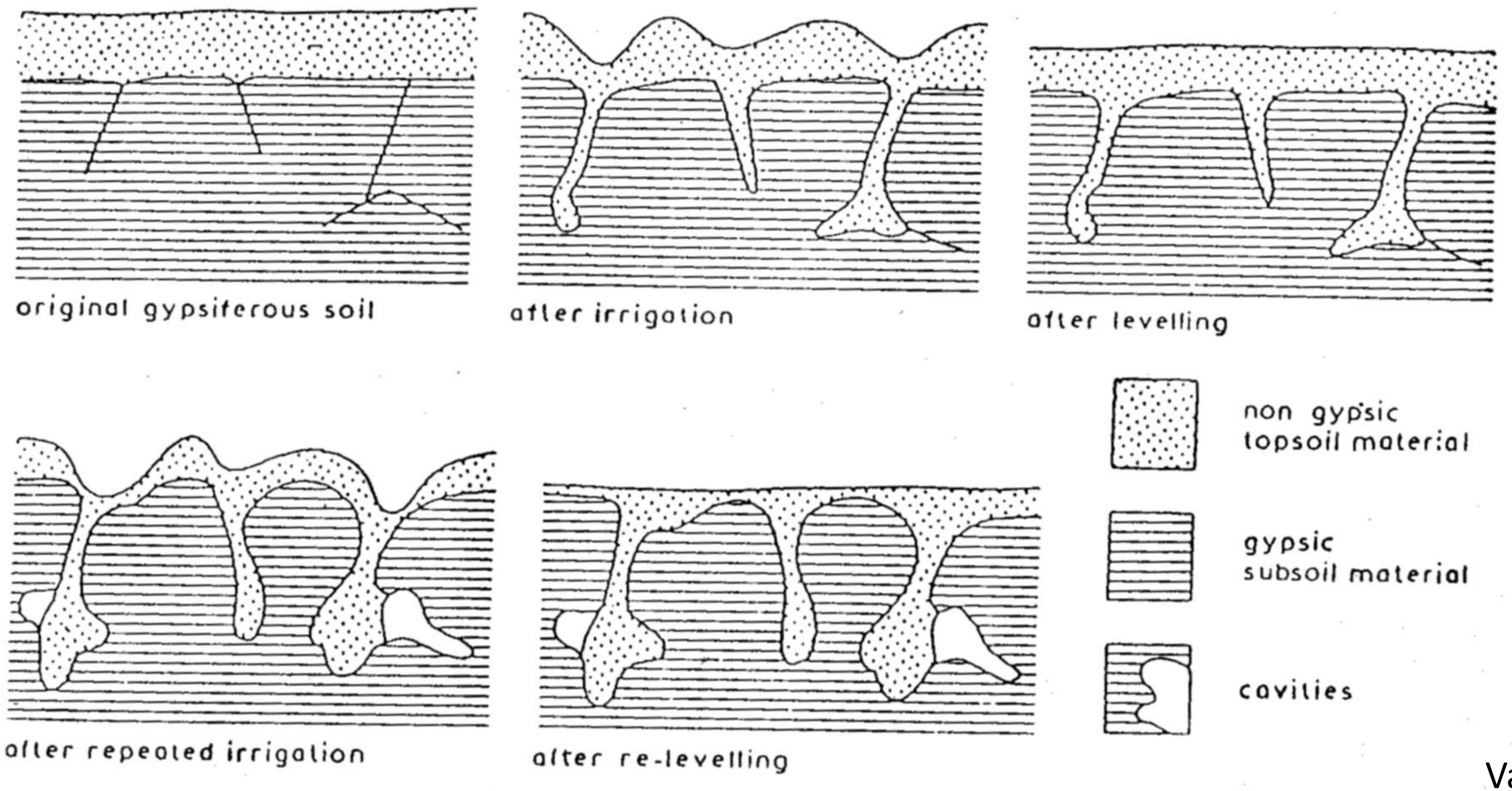


Figure 1 Exposure of a gypsic subsoil layer and cavity formation as a consequence of prolonged irrigation of **gypsiferous** soils (**schematically**).

Van Zuidam and Ríos Romero 1976

Gypsiferous soils: analytical and classification challenges

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Gypsiric material (WRB)
Hypergypsic qualifiers

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Inceptisols	Gypsic

Haploxerepts
WRB:
Gypsisols, Gypsiric qualifier in other RSG

Gypsiferous soils: analytical and classification challenges

Analytical problems

- Very difficult to reach dispersion of clays in texture analyses

  Hesse, P. R. (1976). Particle size distribution in gypsic soils. Plant and soil, 44(1), 241-247.
  Vieillefon, J. (1979). Contribution à l'amélioration de l'étude analytique des sols gypseux. Cahiers ORSTOM, 17(3), 195-223.

- Determination of gypsum: different methods (acetone, dehydration, TGA, …), different precision and accuracy.

  Álvarez D, Antúnez M, Porras S, Rodríguez R, Olarieta JR, Poch RM. (2022). Quantification of gypsum accumulations in soils: methodological proposal. Spanish Journal of Soil Science. 10.3389/sjss.2022.10669

- Avoid heating above 40ºC
- Will always give EC about 2.3 dS/m at 25ºC regardless of the soil/water ratio
- Extractable cations when analyzing CEC: calculate Ca by substraction.

Thank you

Calcareous and gypsiferous soils –
Characteristics, challenges, and innovations
July 2, 2025