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College of Soil Physics

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Soils of the world and their physical properties

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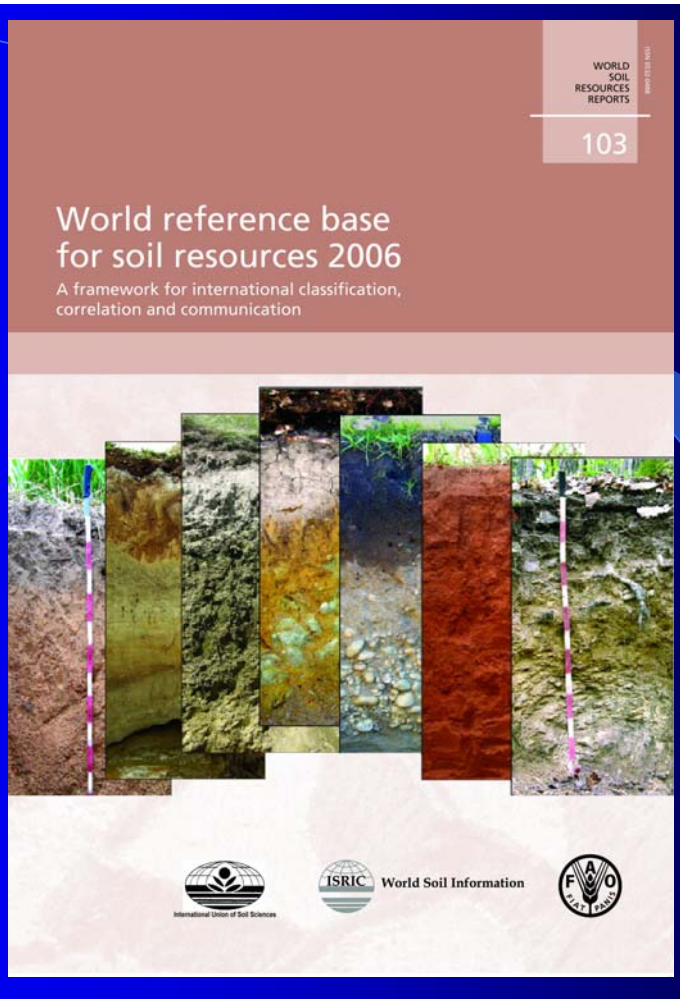
Major Soils of the World

- and their physical properties -

Otto Spaargaren

ISRIC – World Soil Information

Wageningen – The Netherlands



Major soil groupings (1)

- Organic soils (*Histosols*)
- Soils conditioned by man (*Anthrosols, Technosols*)
- Soils conditioned by parent material (*Andosols, Arenosols, Vertisols*)
- Soils conditioned by topography (*Fluvisols, Gleysols, Stagnosols, Leptosols, Regosols*)
- Soils conditioned by time (*Cambisols*)

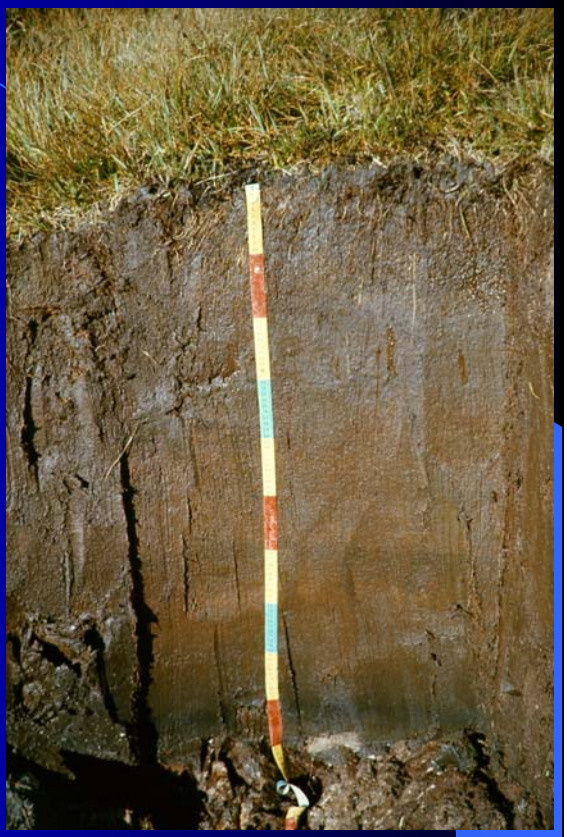
Major soil groupings (2)

- Soils conditioned by climate:
  - Tropical and subtropical (*Ferralsols, Acrisols, Lixisols, Nitisols, Alisols, Plinthosols*)
  - Arid and semi-arid (*Gypsisols, Durisols, Calcisols, Solonchaks, Solonetz*)
  - Steppe (*Chernozems, Kastanozems, Phaeozems*)
  - Temperate (*Luvisols, Albeluvisols, Podzols, Planosols, Umbrisols*)
  - Cold (*Cryosols*)

Histosols

Influenced by excess of water, resulting in accumulation of organic materials

Excess of water is caused either by groundwater or by precipitation largely surmounting evapotranspiration

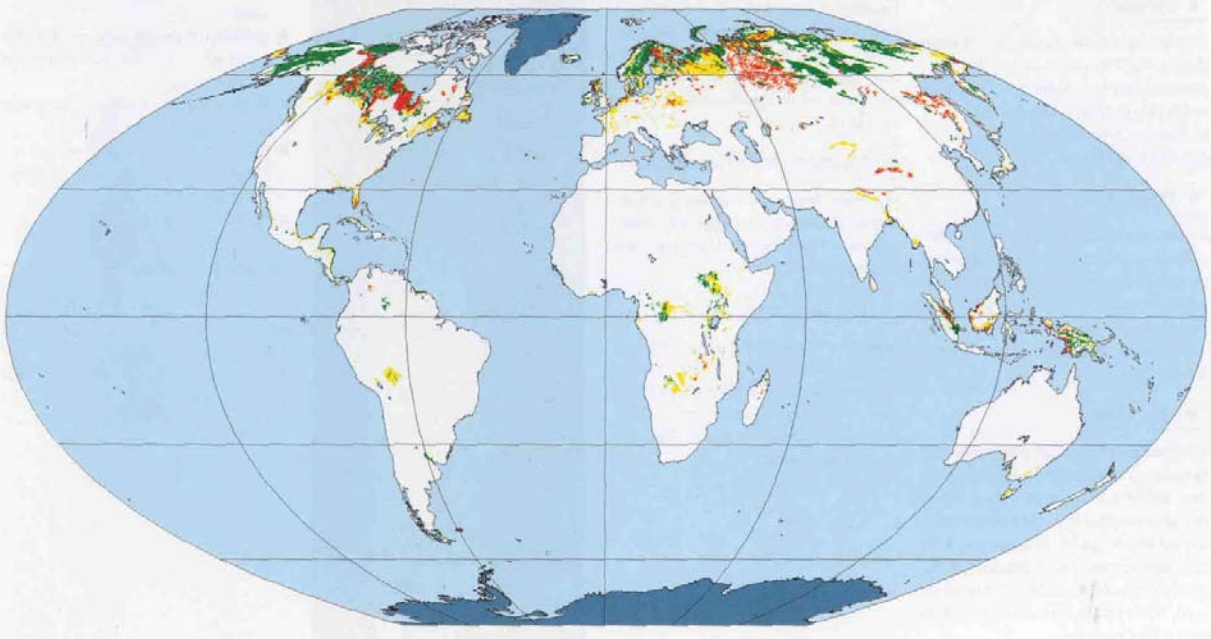


Histosols

Physical properties:

- High water content
- High organic matter content
- Low bulk density
- High groundwater table
- Low bearing capacity
- Subject to subsidence upon drainage

• Distribution of Histosols •



Dominant | Associated | Inclusions | Miscellaneous lands (Glaciers, No data)

Flat Polar Quartic Projection

FAO-GIS, February 1998

Soils conditioned by parent material

- ***Andosols*** *(soils in pyroclastic deposits)*
- ***Arenosols*** *(sandy soils)*
- ***Vertisols*** *(cracking clay soils)*

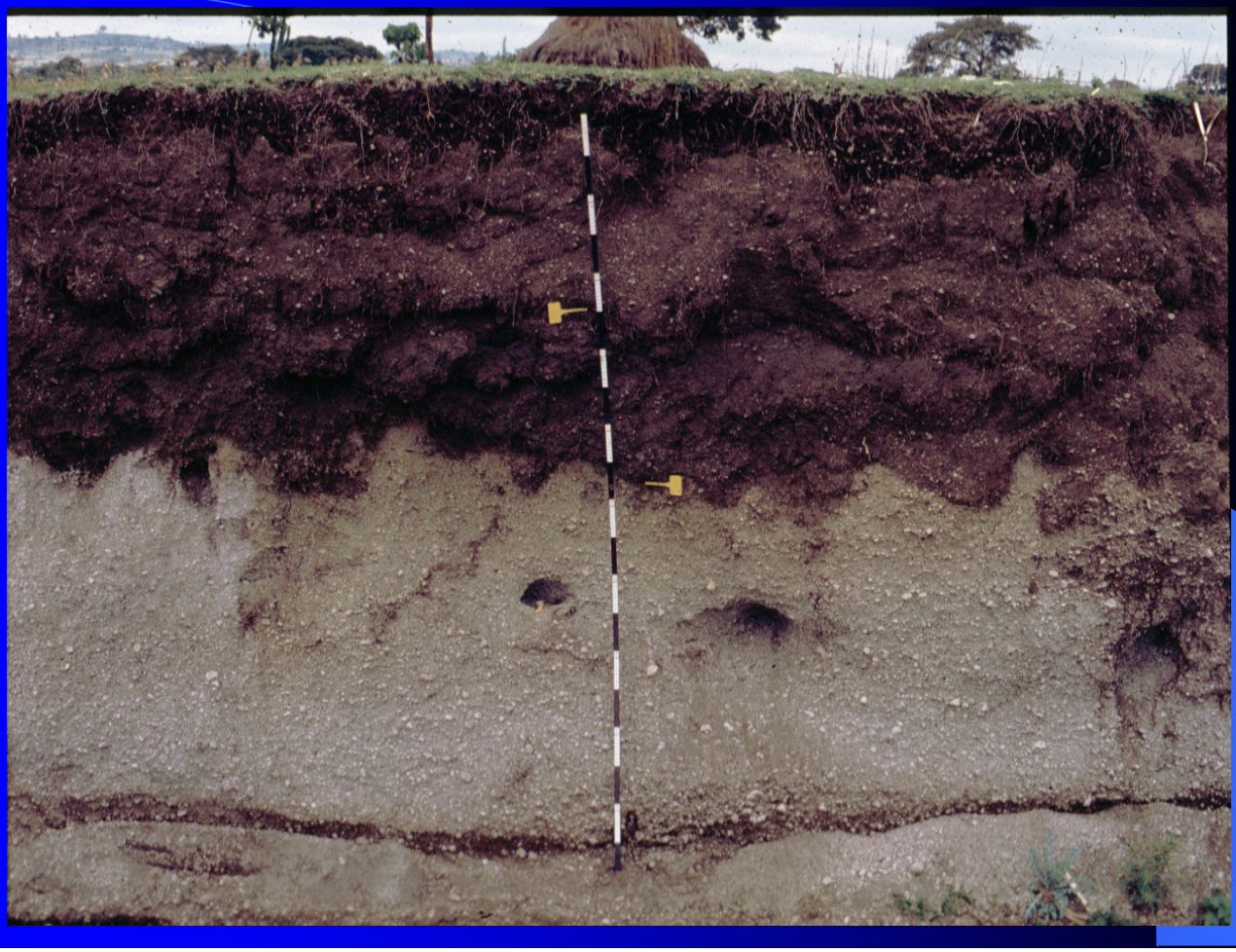
Andosols

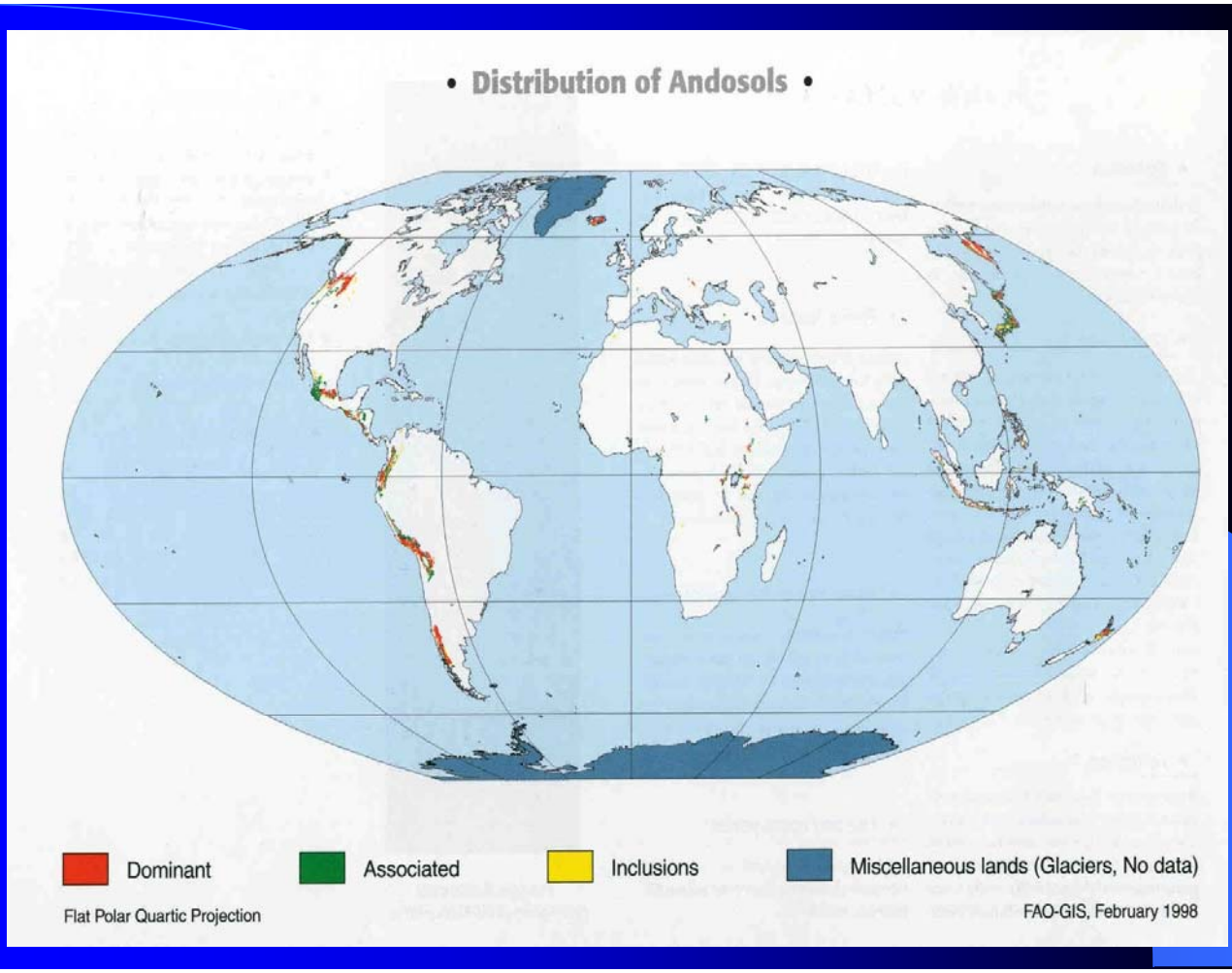
- Rapidly weathering pyroclastic deposits, producing:
  - Under non- or slightly acid conditions such minerals as allophane and imogolite
  - Under acid conditions aluminium-organic complexes

Andosols

Physical properties:

- **Low bulk density** (less than 0.9 kg/dm^3)
- **High water-holding capacity**
- Sometimes ***thixotropic***, i.e. the soil material changes, under pressure or rubbing, from a plastic solid into a liquid stage and back into the solid condition



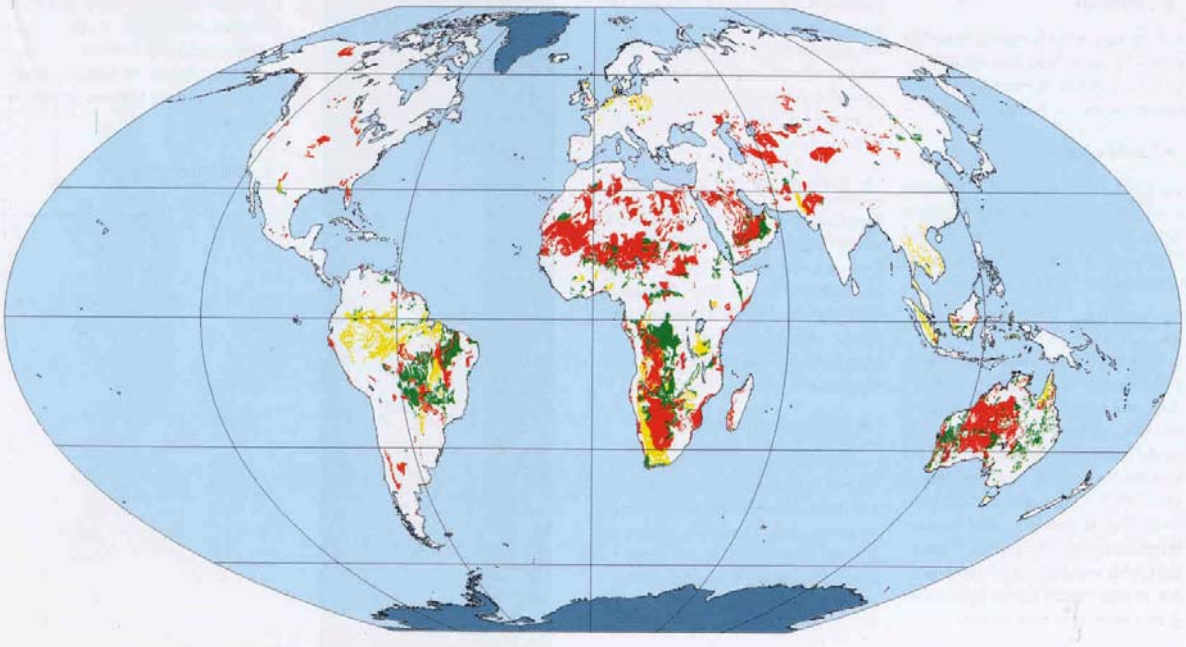

• Distribution of Andosols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Arenosols

Physical properties:

- Loamy sand or sandy texture to a depth of 100 cm
- Low water-holding capacity
- Easy to work

• Distribution of Arenosols •



Dominant Associated Inclusions Miscellaneous lands (Glaciers, No data)

Flat Polar Quartic Projection

FAO-GIS, February 1998

Vertisols

Soils that develop in shrink-swell clays.

Physical properties:

- Wide cracks when dry
- Low porosity (mainly only micropores) and low water transmission capacity
- Irregular surface topography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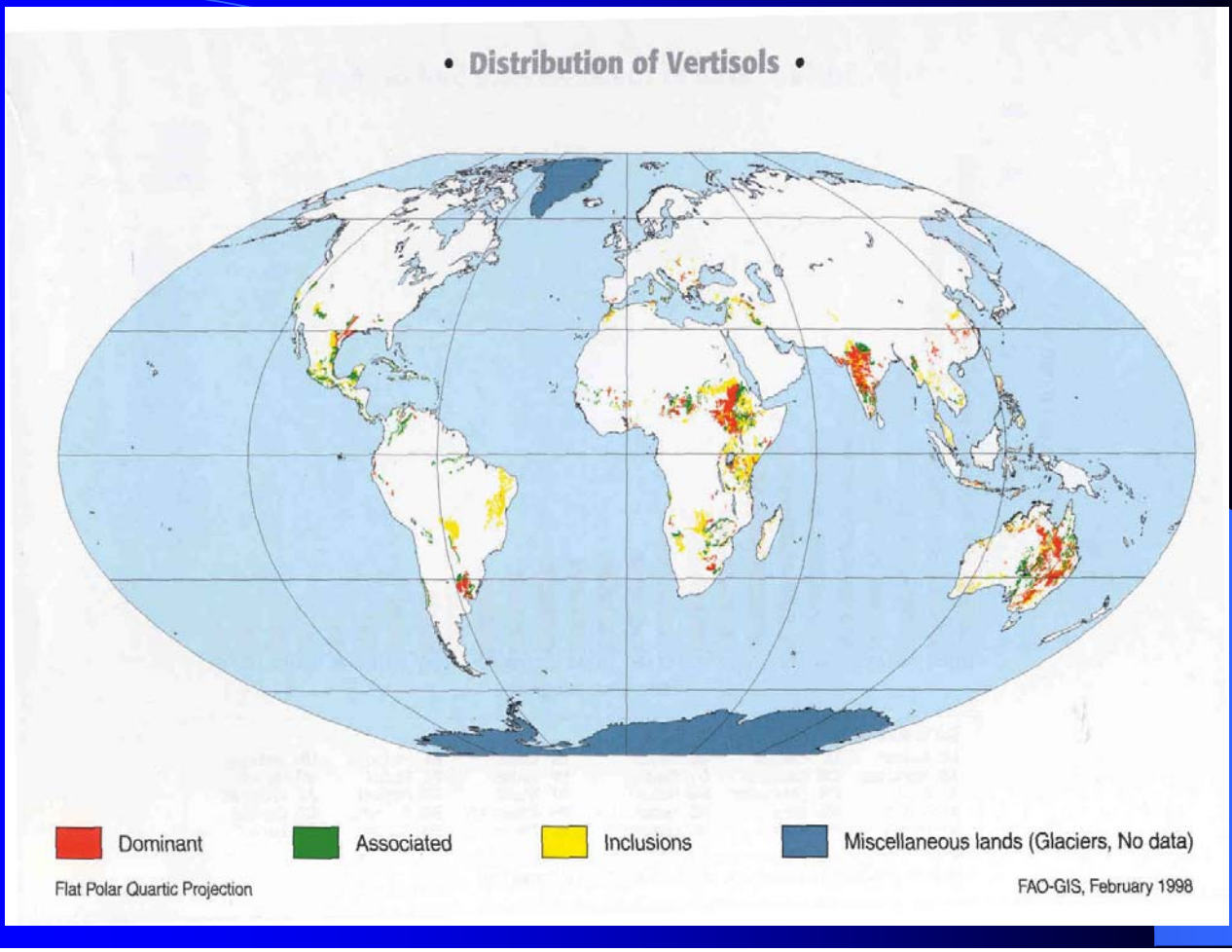


Soils conditioned by topography

- ***Fluvisols*** *(soils in alluvial deposits)*
- ***Gleysols*** *(groundwater wet soils)*
- ***Stagnosols*** *(surface wet soils)*
- ***Leptosols*** *(shallow or extremely gravelly soils)*
- ***Regosols*** *(undeveloped, medium textured soils)*

Fluvisols

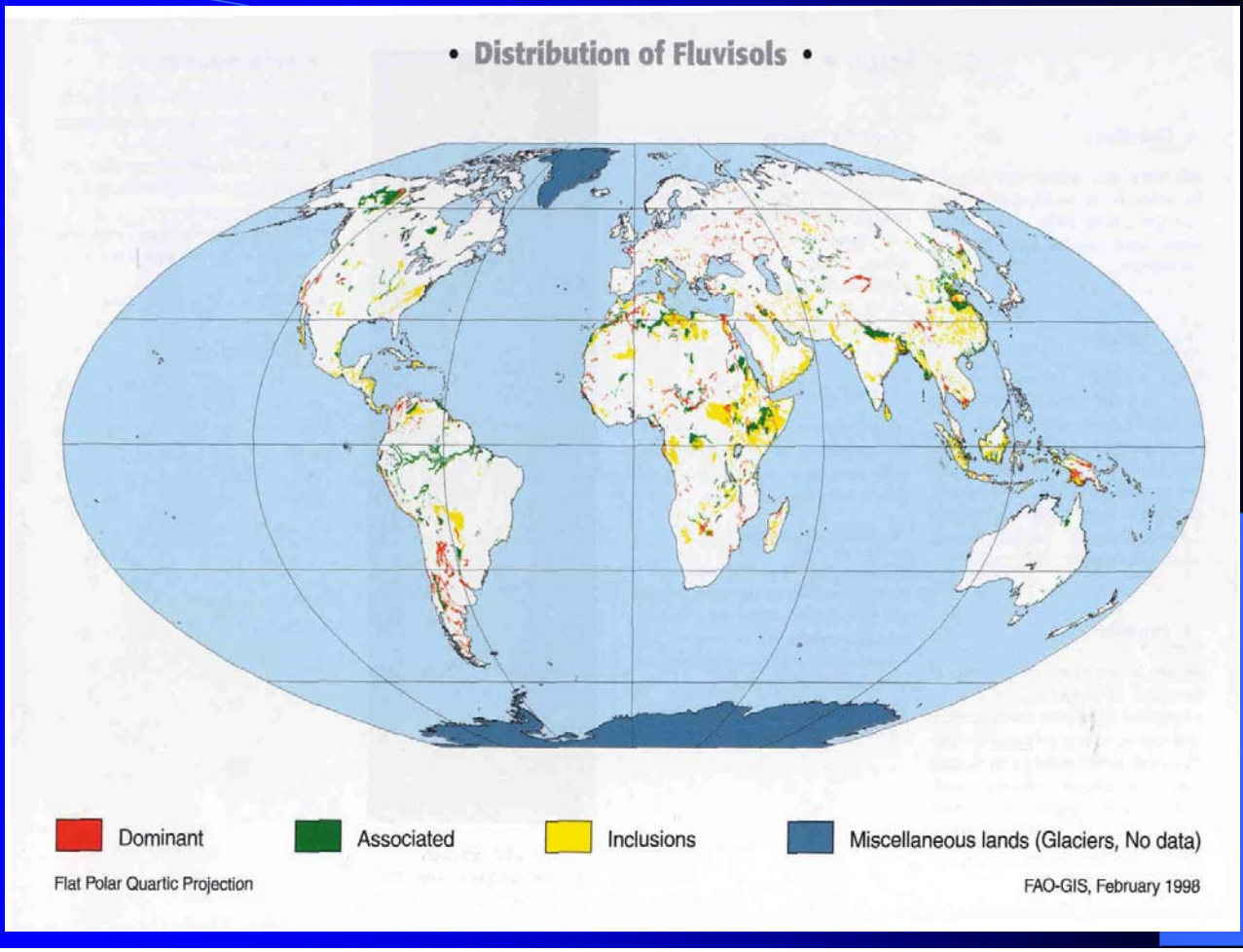
Soils in (sub-)recent alluvial, marine or lacustrine deposits, receiving at regular intervals new material (or having received this material in the recent past).

They vary widely in texture, from clay to gravel, and have an organic matter content that is distributed irregularly in the soil.

Fluvisols

Physical properties:

- Stratification influences water movement through the soil
- Recently deposited fine-textured Fluvisols have a high water content, low bulk density and low bearing capacity
- Medium- and fine textured Fluvisols develop crusts and cracks upon drying

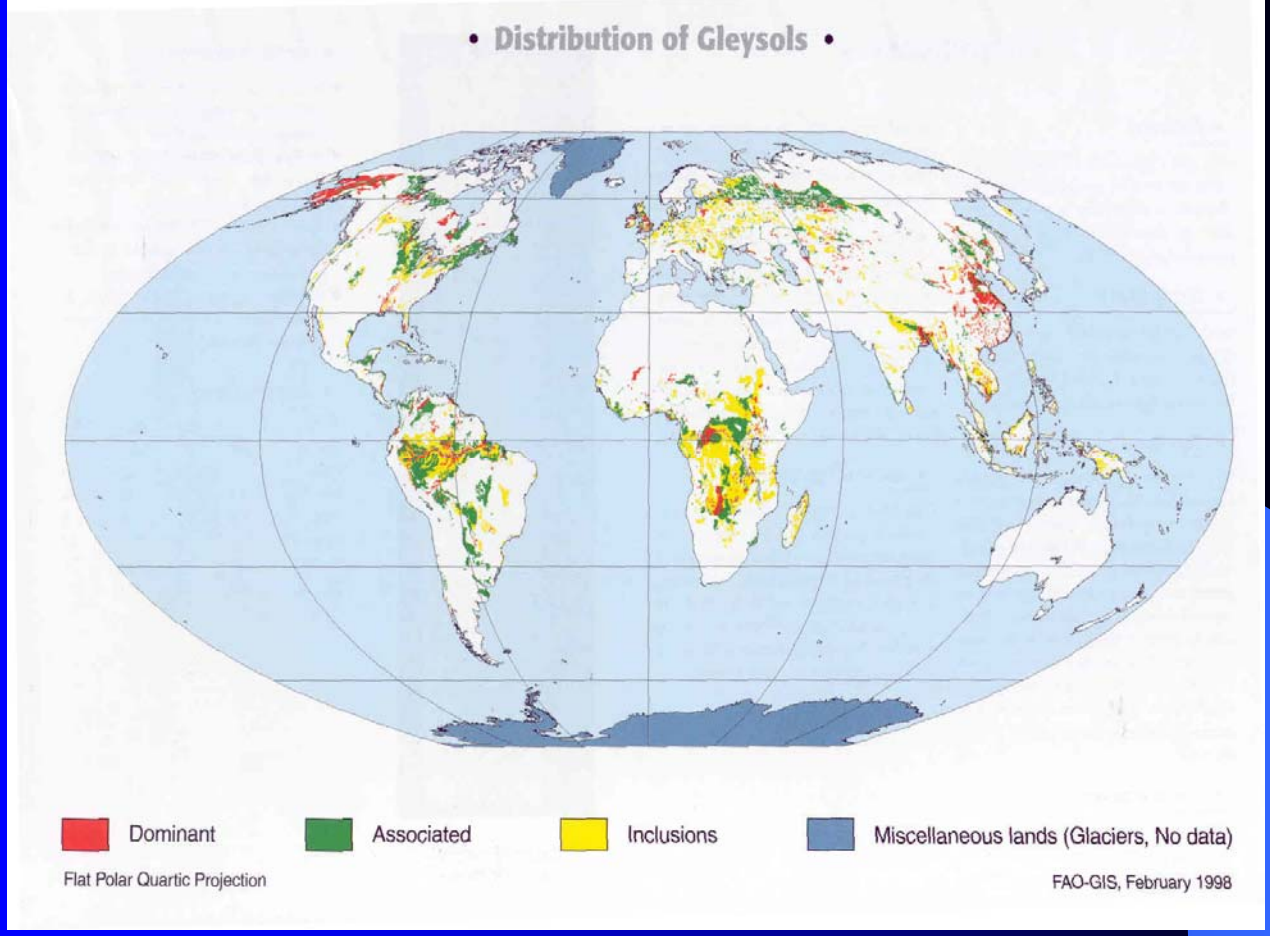


Gleysols

Soils that are permanently or temporarily saturated with groundwater within 50 cm from the soil surface.

Characteristic are features associated with the reduction and oxidation of iron and manganese; oxidation along pores and root channels, reduction in the matrix.

Gleysols have poor internal drainage.

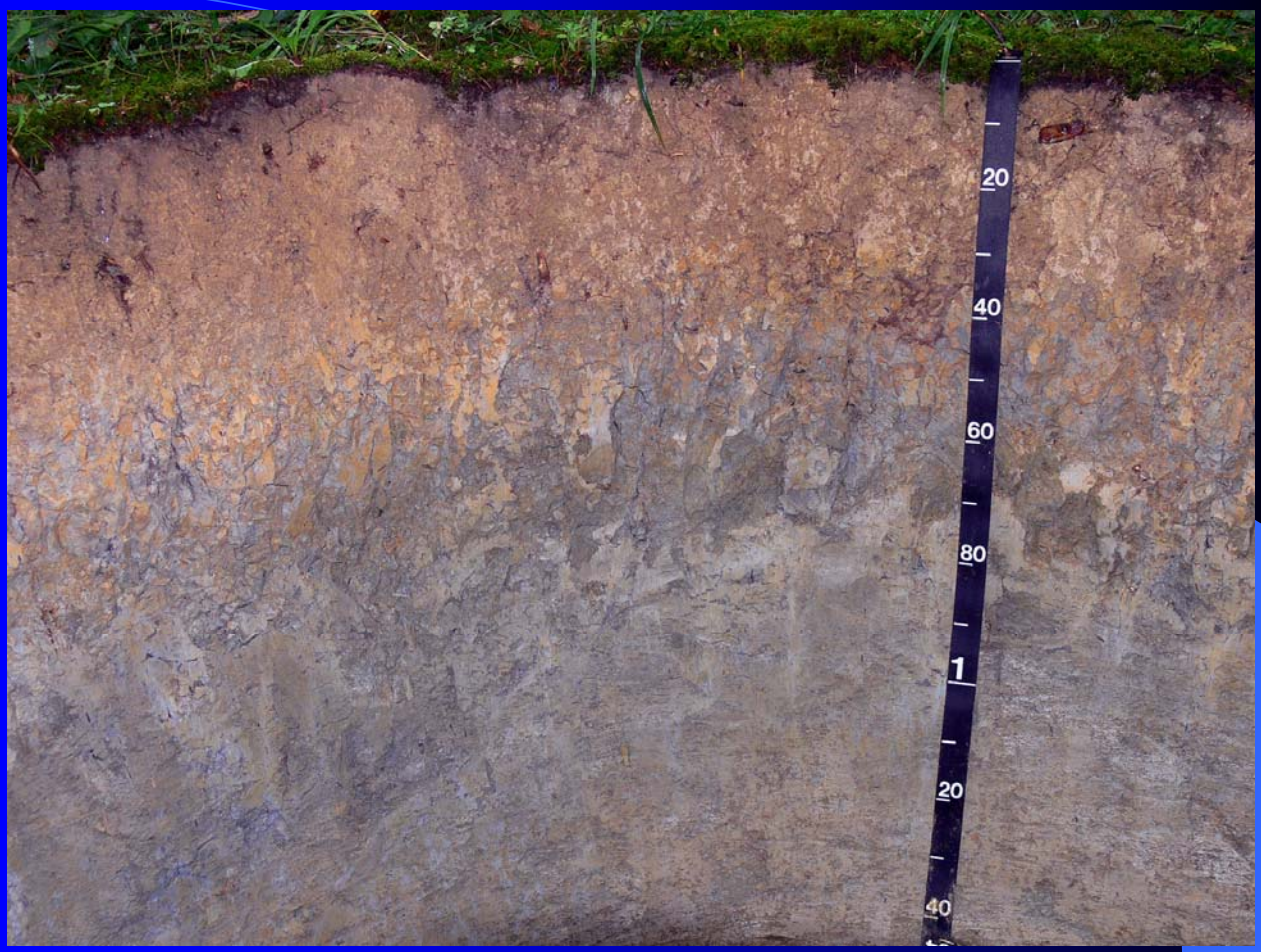


Stagnosols

Soils that are temporarily saturated with stagnant water within 50 cm from the soil surface.

Characteristic are features associated with the redistribution of iron and manganese and the presence of a slowly permeable layer near to the surface.

Stagnosols have very slow vertical water movement and drain normally in lateral direction.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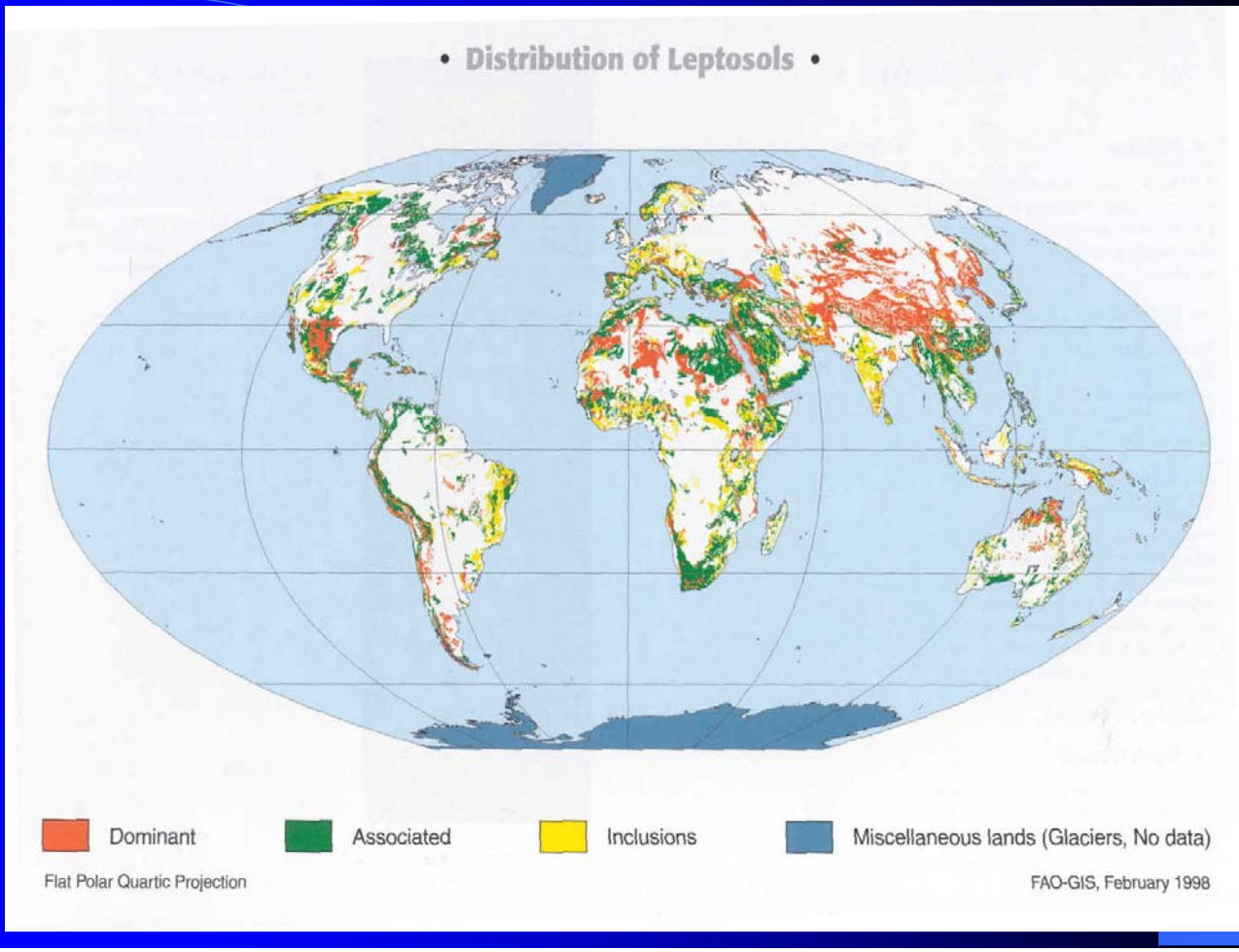
Leptosols

Soils that are either shallow (< 25 cm deep) over hard rock, or that are extremely gravelly (> 80% gravel, stones or boulders by volume)

Physical properties:

- Low water-holding capacity due to their limited depth or extreme coarse texture
- On slopes prone to erosion

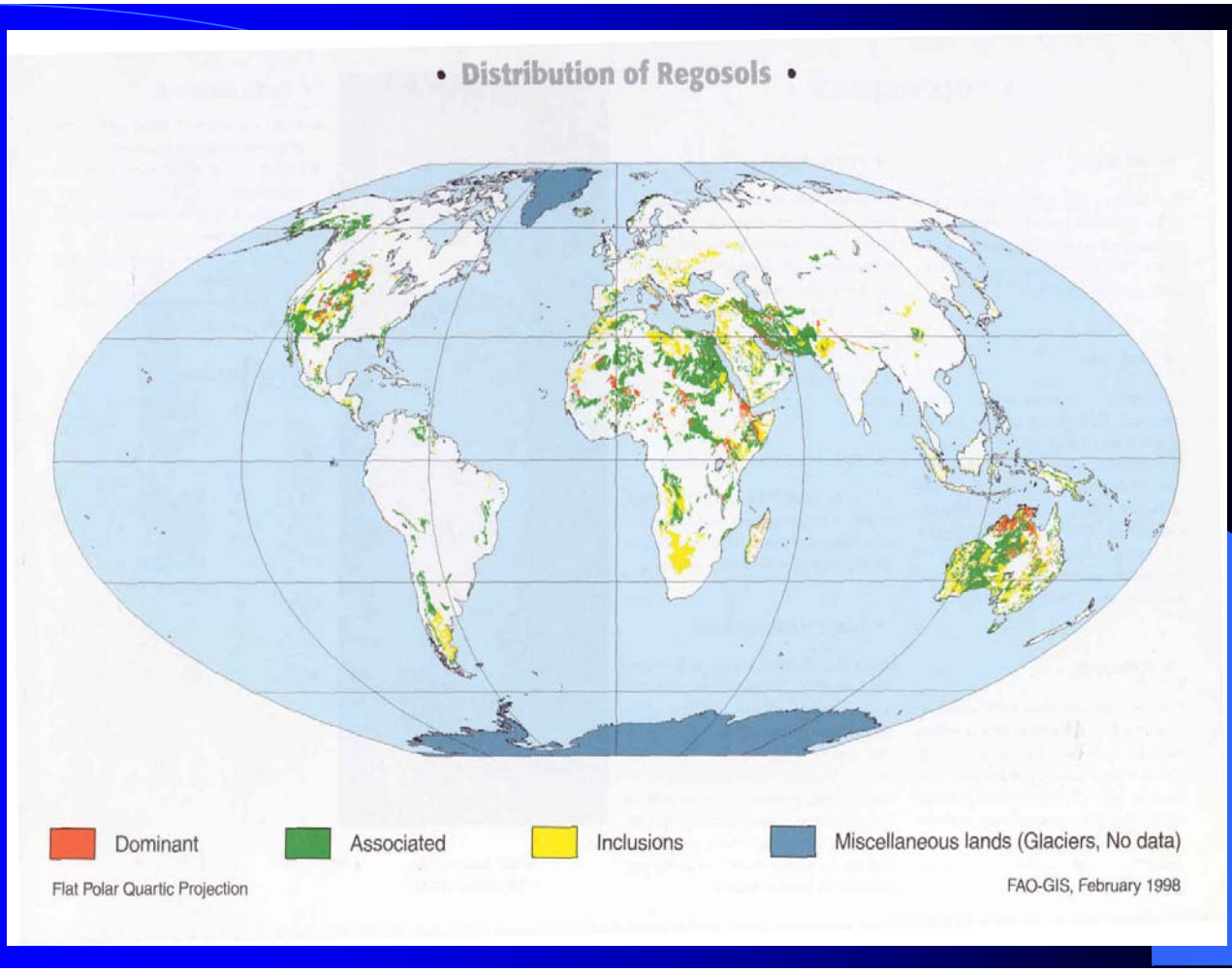

• Distribution of Leptosols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Regosols

Weakly developed soils in unconsolidated materials that are not very shallow *(Leptosols)*, or sandy *(Arenosols)*, or wet *(Gleysols)*, or that consist of alluvial material *(Fluvisols)*.

Physical properties:

- Structureless due to lack of cohesion between the soil particles
- Often prone to erosion


• Distribution of Regosols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Soils conditioned by time

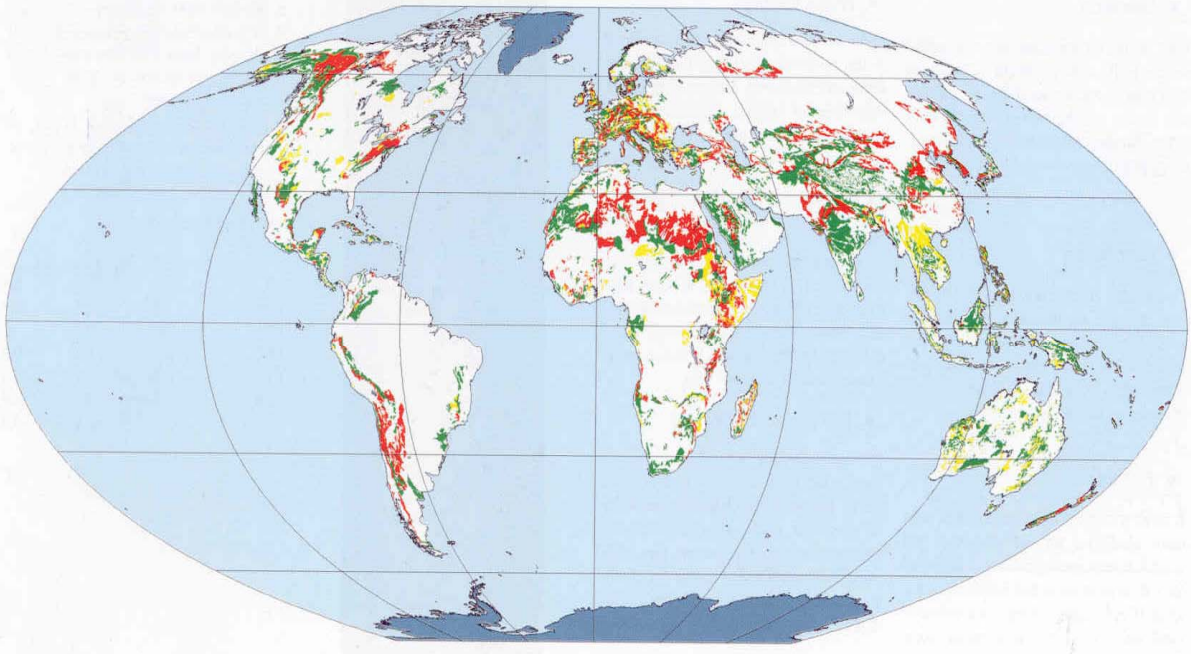
Cambisols *(moderately developed soils with beginning horizon differentiation evident from changes in colour, structure or carbonate content)*

Cambisols

Physical properties:

- Good structural stability
- High porosity
- Good water-holding capacity
- Good internal drainage
- Not much prone to erosion

• Distribution of Cambisols •



Dominant

Associated

Inclusions

Miscellaneous lands (Glaciers, No data)

Flat Polar Quartic Projection

FAO-GIS, February 1998

Soils conditioned by climate

- Tropical and subtropical (*Ferralsols, Acrisols, Lixisols, Nitisols, Alisols, Plinthosols*)
- Arid and semi-arid (*Gypsisols, Durisols, Calcisols, Solonchaks, Solonetz*)
- Steppe (*Chernozems, Kastanozems, Phaeozems*)
- Temperate (*Luvisols, Albeluvisols, Podzols, Planosols, Umbrisols*)
- Cold (*Cryosols*)

Soils conditioned by tropical and subtropical climates

- ***Ferralsols*** *(strongly leached soils with a* ***ferralic*** *horizon)*
- ***Acrisols*** *(strongly leached acid soils with a low activity* ***argic*** *horizon)*
- ***Lixisols*** *(other strongly leached soils with a low activity* ***argic*** *horizon)*
- ***Nitisols*** *(soils with a* ***nitic*** *horizon)*
- ***Alisols*** *(strongly acid soils rich in aluminium)*
- ***Plinthosols*** *(wet soils with* ***plinthite****)*

Ferralsols

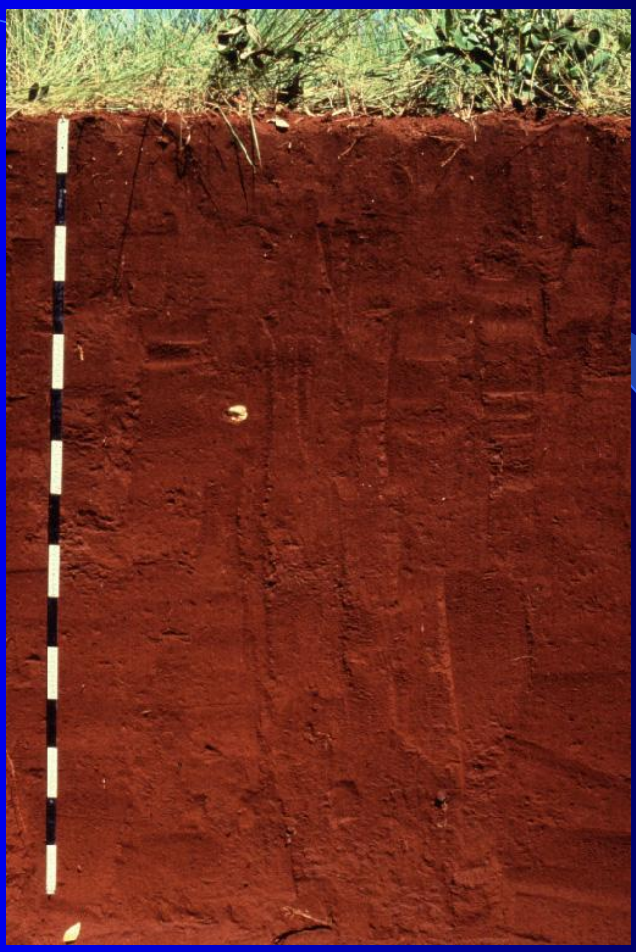
Strongly leached soils with accumulation of:

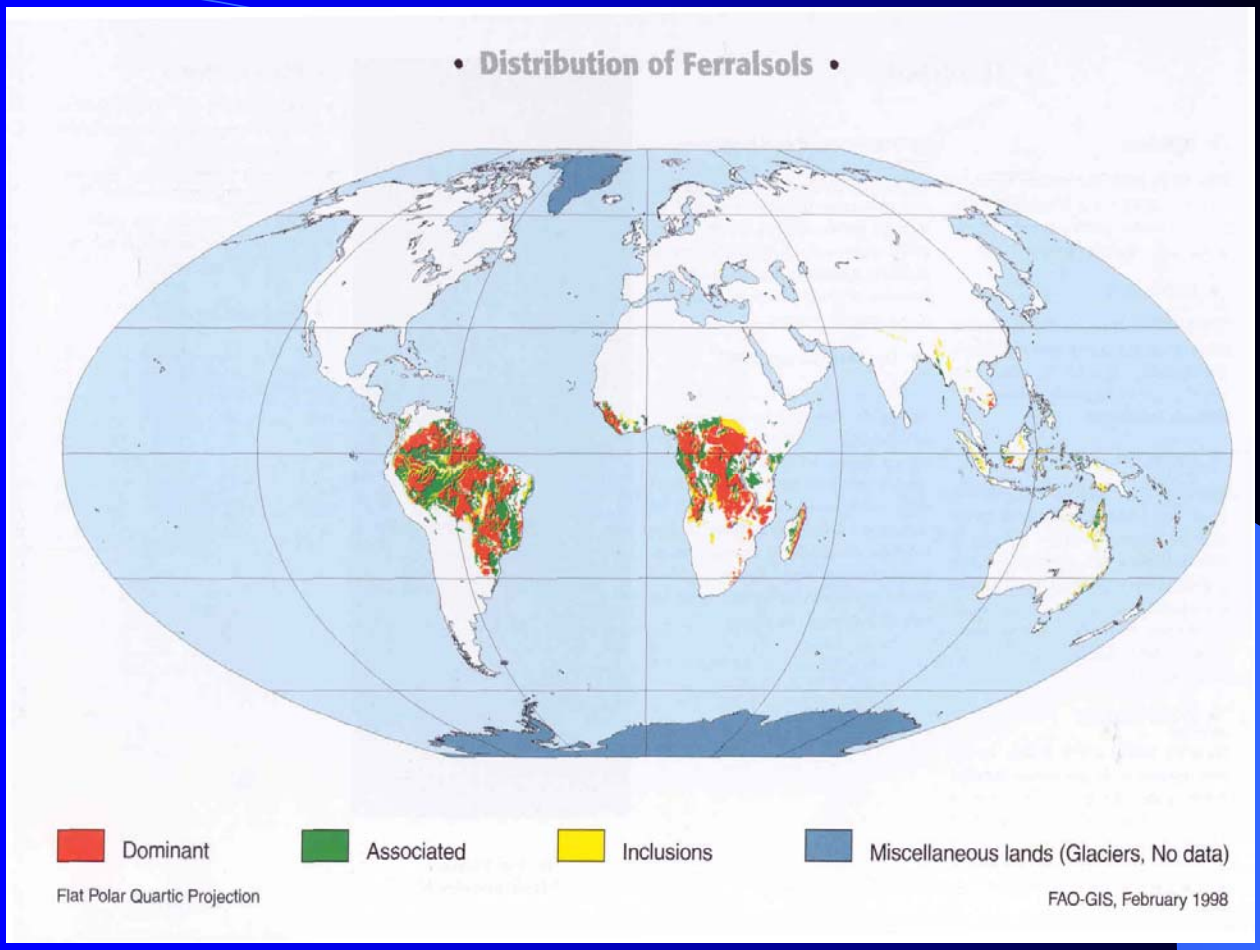
- Iron(hydr)oxides *(goethite, hematite)*
- Aluminium(hydr)oxides *(gibbsite)*
- Low activity clay *(e.g. kaolinite)*
- Residual quartz and other weathering-resistant minerals

Ferralsols

Physical properties:

- Very stable microstructure (*pseudosand* and *pseudosilt* textures)
- Good water-holding and water-transmission capacity
- Low bulk density (around 1.0 kg/dm^3)
- Not much prone to erosion





Acrisols

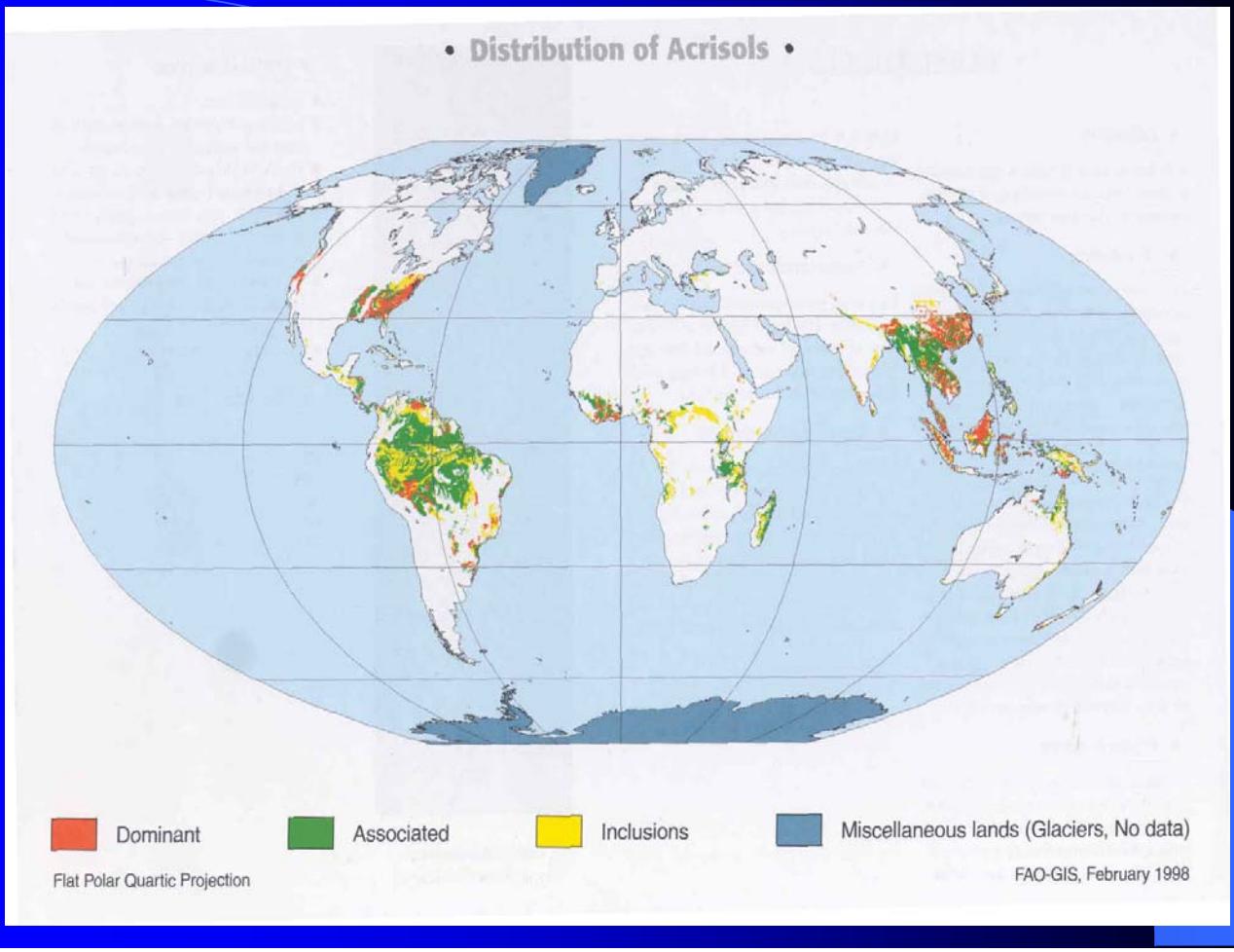
Strongly leached soils with

- Pronounced increase in clay content with depth *(argic horizon)*
- Dominance of low activity clay
- Acid to strongly acid soil reaction, indicative of low base saturation

Acrisols

Physical characteristics:

- Weakly developed soil structure, particularly in the upper part of the soil
- Often hard-setting when dry
- Prone to slaking, crusting and erosion



Lixisols

Strongly leached soils with

- Pronounced increase in clay content with depth *(argic horizon)*
- Dominance of low activity clay
- Slightly acid to neutral soil reaction, indicative of moderate to high base saturation

Lixisols

Physical characteristics:

- Weakly developed soil structure, particularly in the upper part of the soil
- Often hard-setting when dry
- Prone to slaking, crusting and erosion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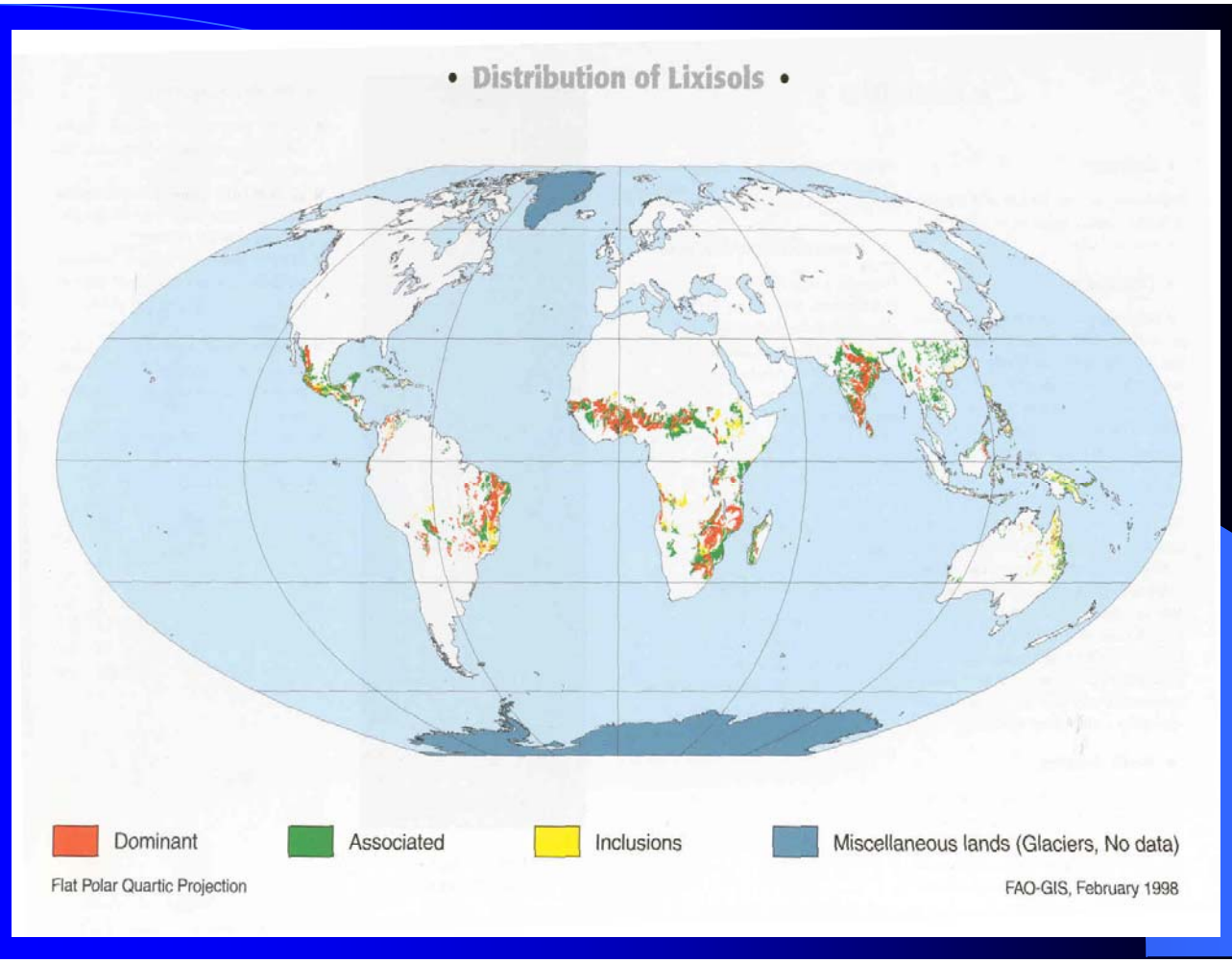
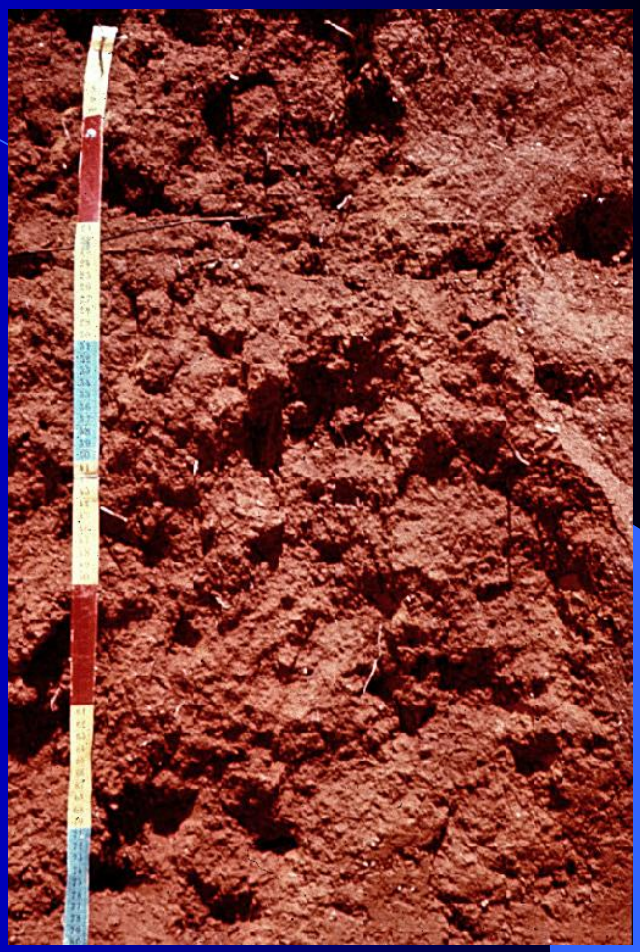

• Distribution of Lixisols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

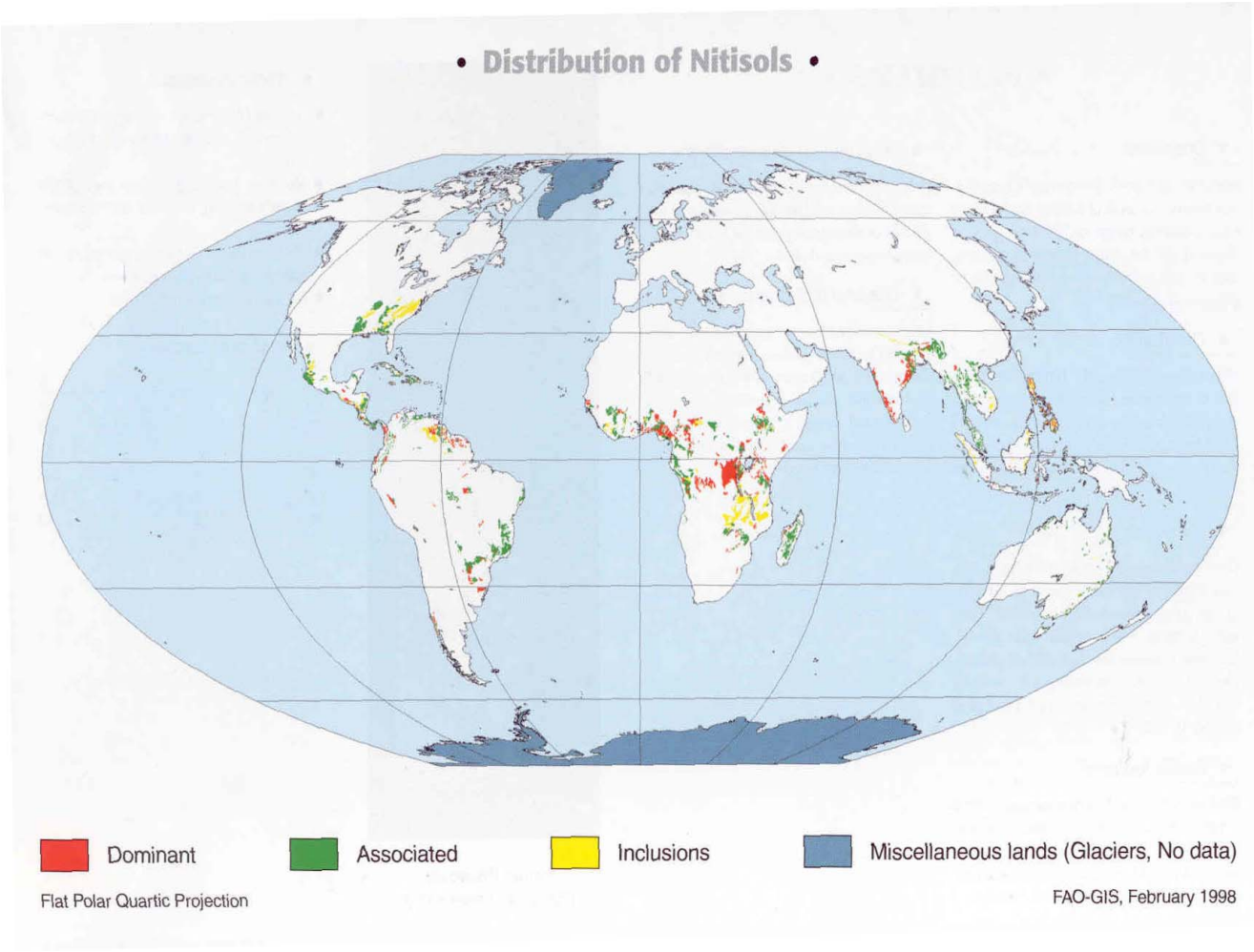
Nitisols

Soils that have strongly developed nut-shaped structure, mainly derived from basic rock. Iron plays an important role.

Physical properties:

- Good water-holding capacity
- Good structural stability
- Not much prone to erosion





Alisols

Soils with a high amount of exchangeable aluminium, which is released from rapidly weathering clay minerals (e.g. chlorite, vermiculite).

Physical properties:

- Strongly developed soil structure
- Prone to slaking, crusting and erosion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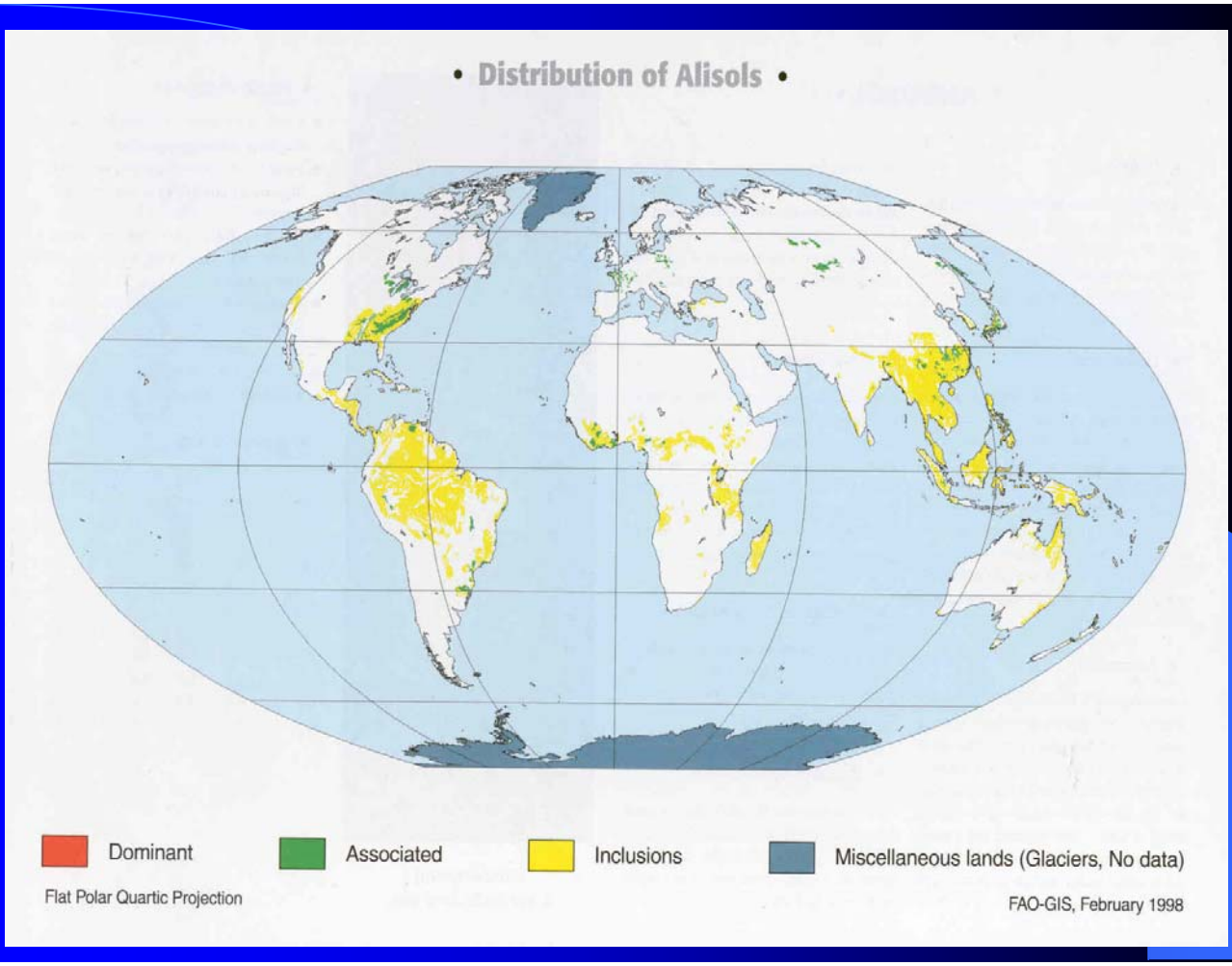

• Distribution of Alisols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Plinthosols

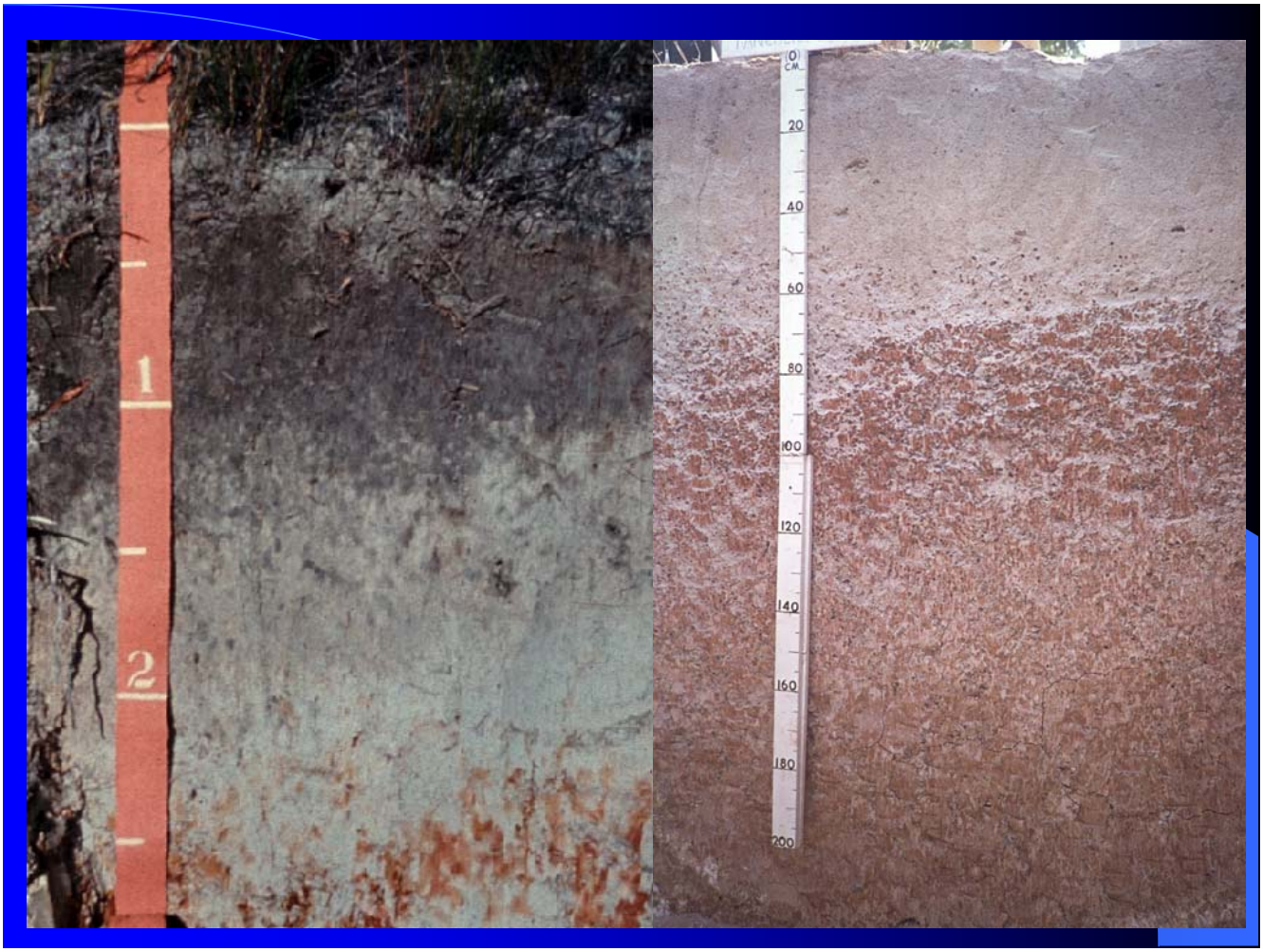
Wet soils with iron accumulation that irreversibly hardens upon repeated drying and wetting *(plinthite)*:

- Low-lying level positions (valley floors, river terraces)
- Form under the influence of groundwater and lateral waterflow from adjacent uplands

Plinthosols

Physical properties:

- Dense subsoil, obstructing deep percolation of water and inhibiting root penetration (bulk density of plinthite varies from 1.8 – 2.2 kg/dm^3)
- Low water storage capacity if *petroplinthite* is close to the surface
- Waterlogging on plinthic layer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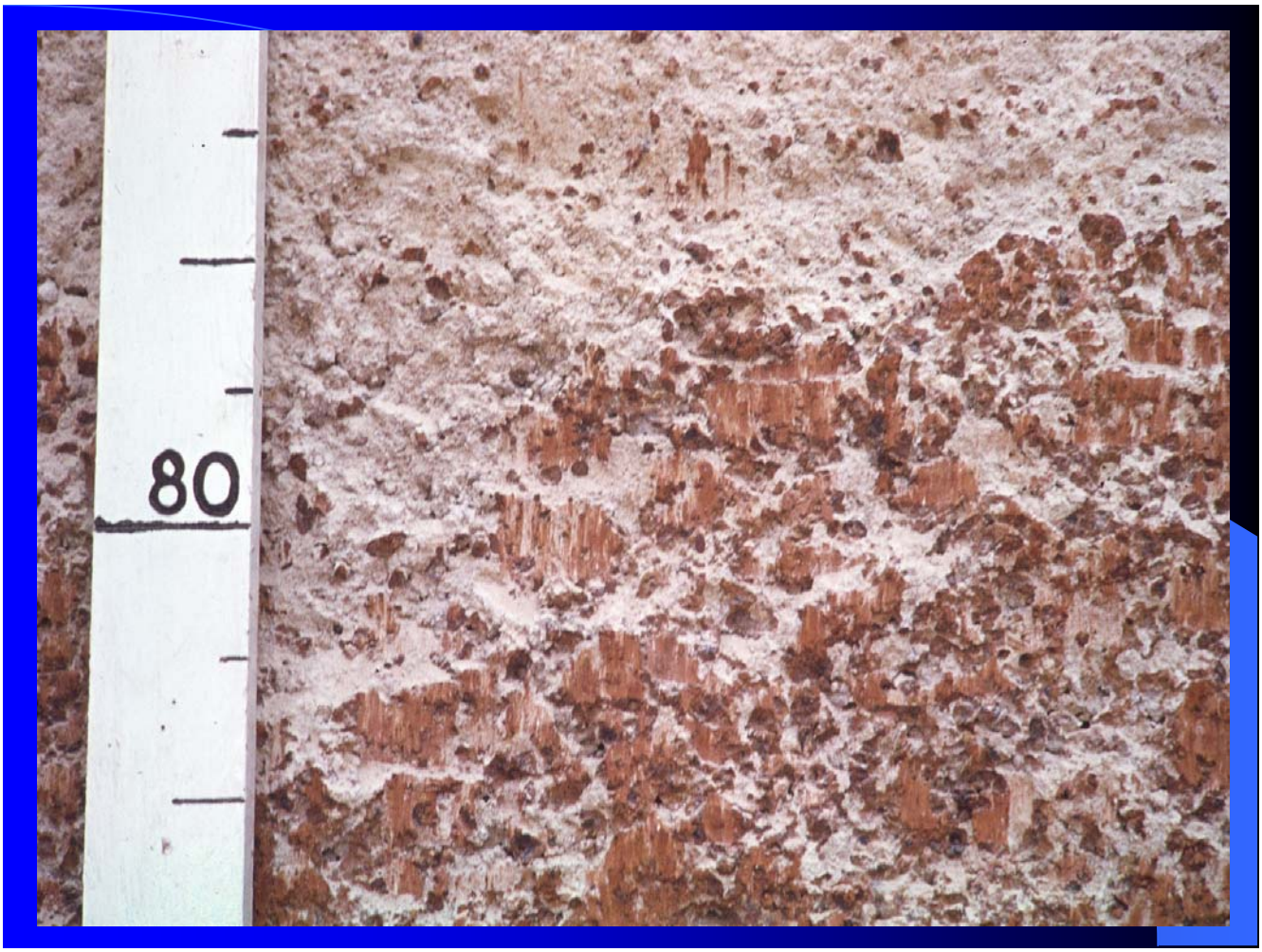
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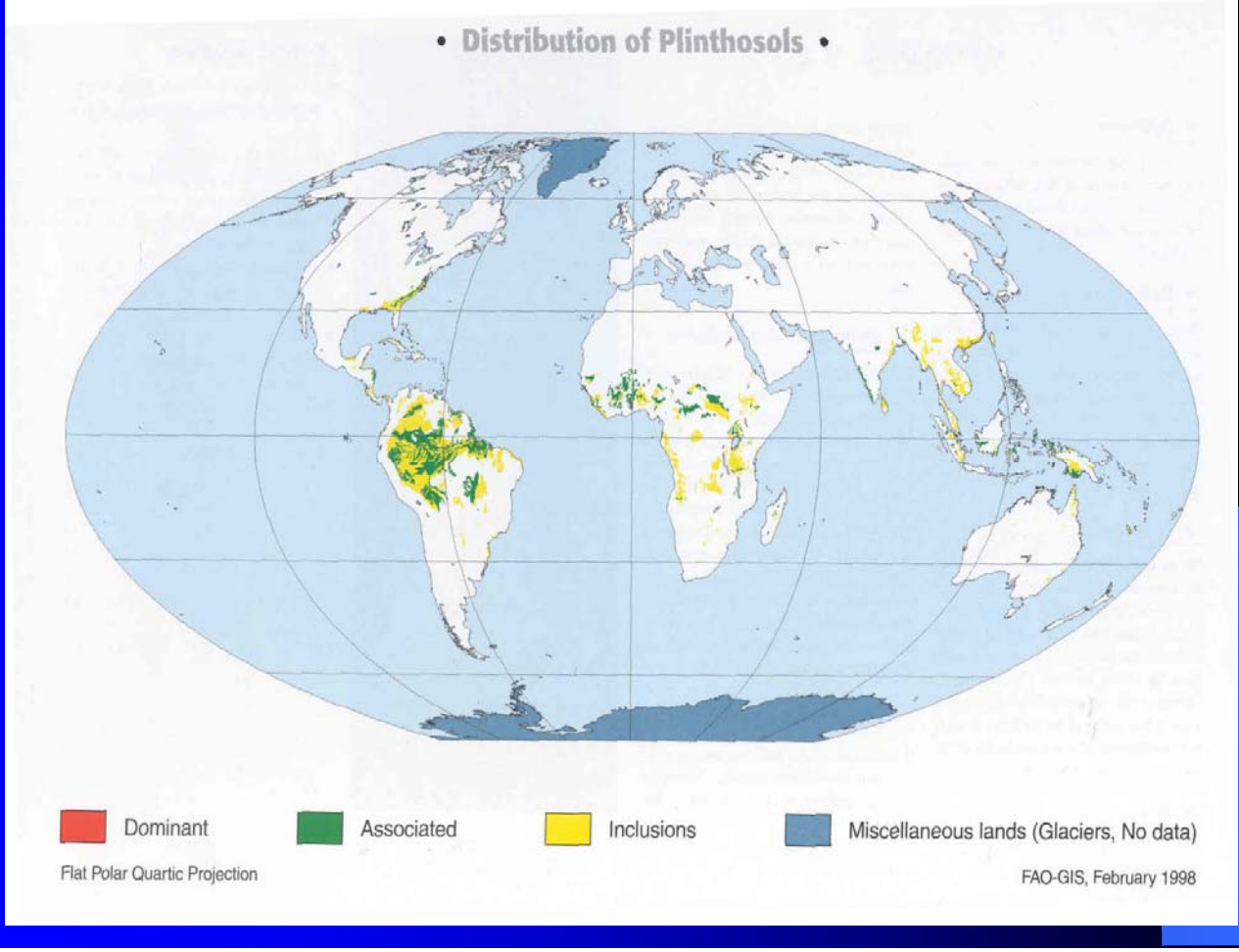

• Distribution of Plinthosols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Soils conditioned by arid and semi-arid climates

- *Gypsisols (accumulation of secondary gypsum)*
- *Durisols (accumulation of secondary silica)*
- *Calcisols (accumulation of secundary calcium carbonate)*
- *Solonchaks (accumulation of soluble salts)*
- *Solonetz (accumulation of sodium)*

Gypsisols

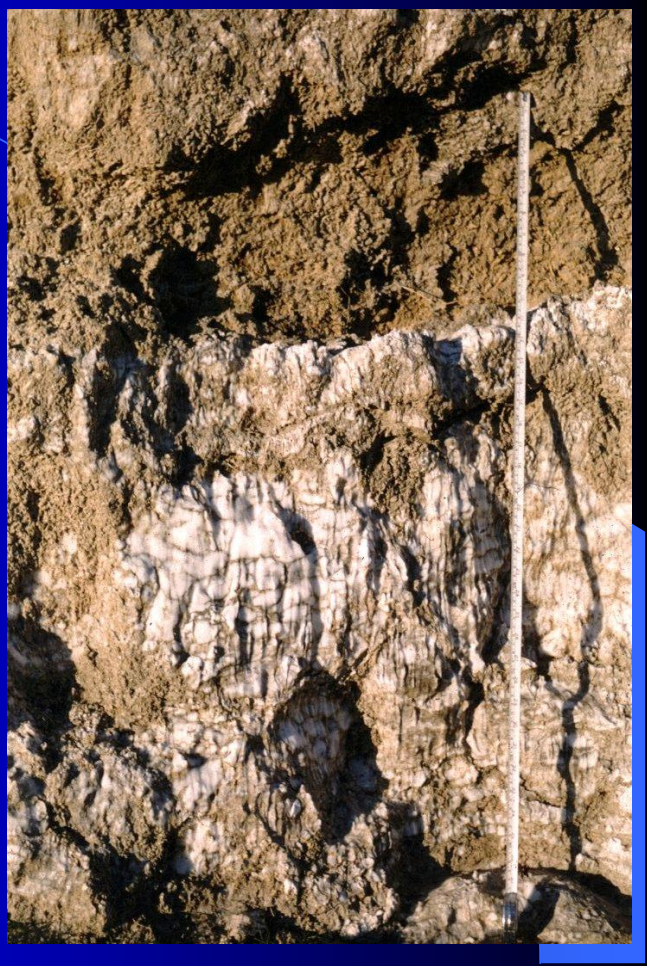
Soils with accumulation of secondary gypsum ($CaSO_4.2H_2O$), forming *gypsic* or *petro-gypsic* horizons:

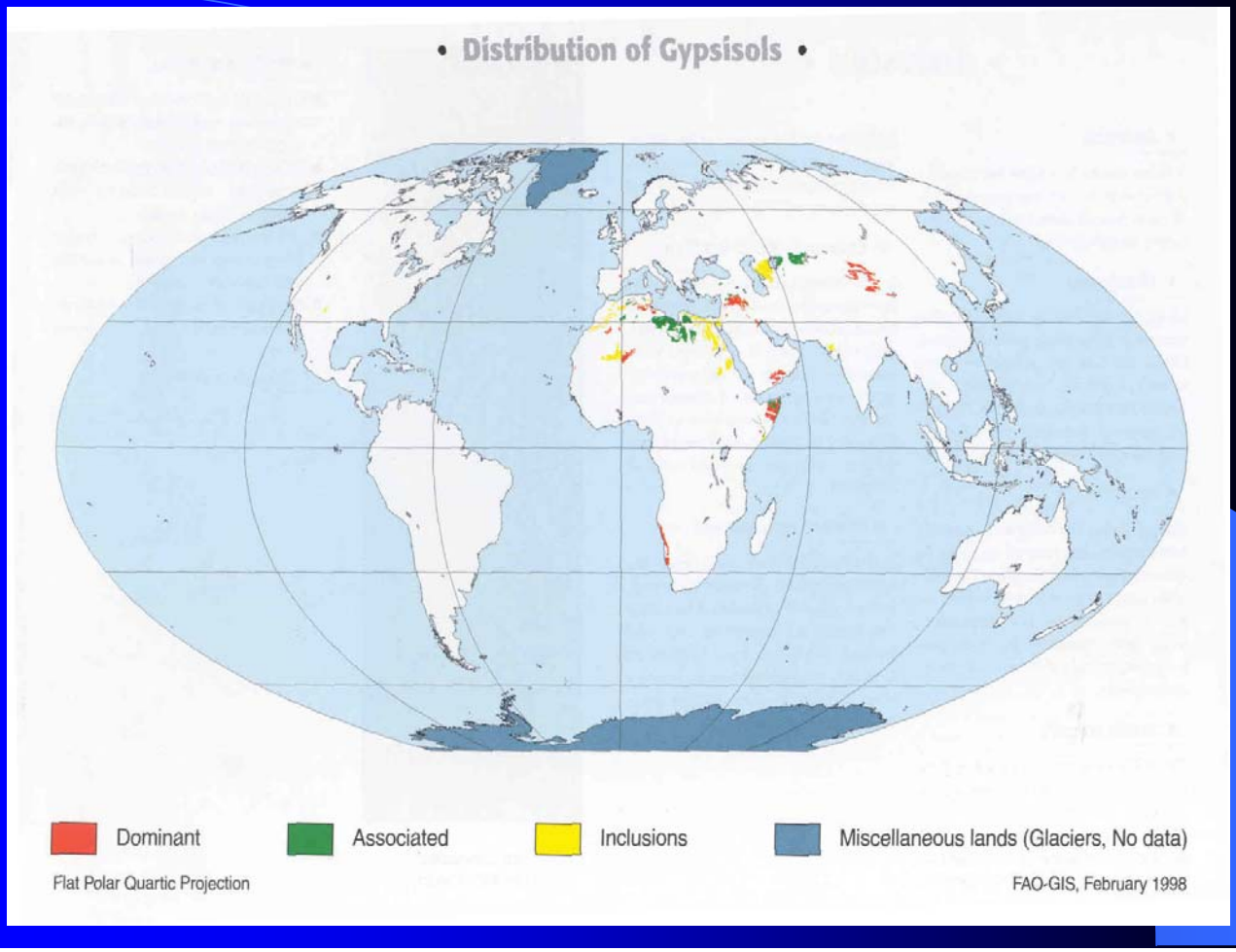
- Gypsic: > 5% gypsum and > 1% visibly secondary gypsum
- Petrogypsic: hardened gypsum bank

Gypsisols

Physical properties:

- Surface slakes easily and crusts on Gypsisols are common
- Low water-holding capacity due to many large pores and caveties that form after dissolution of the gypsum




• Distribution of Gypsisols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Durisols

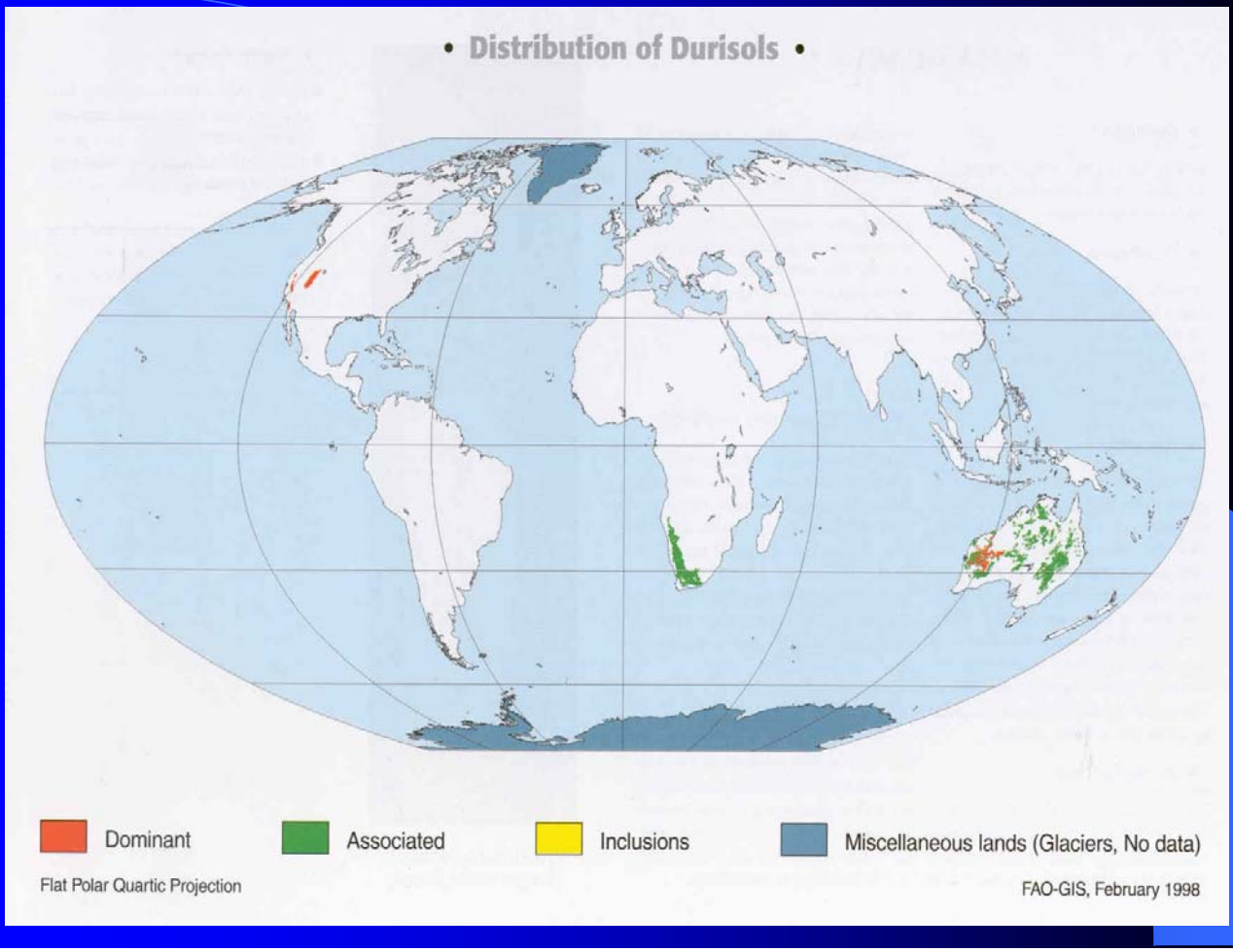
Soils with accumulation of secondary silica, forming *duric* or *petroduric* horizons:

- Duric horizon: accumulation of silica in nodular form *(durinodes)*
- Petroduric horizon: accumulation in hard silica bank *(duripan)*

Durisols

Physical properties:

- Petroduric horizons hamper root penetration, unless they are fractured
- Bulk density of duric horizons varies between 1.3 and 1.7 kg/dm^3, that of the petroduric horizon between 1.6 and 2.0 kg/dm^3


• Distribution of Durisols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Calcisols

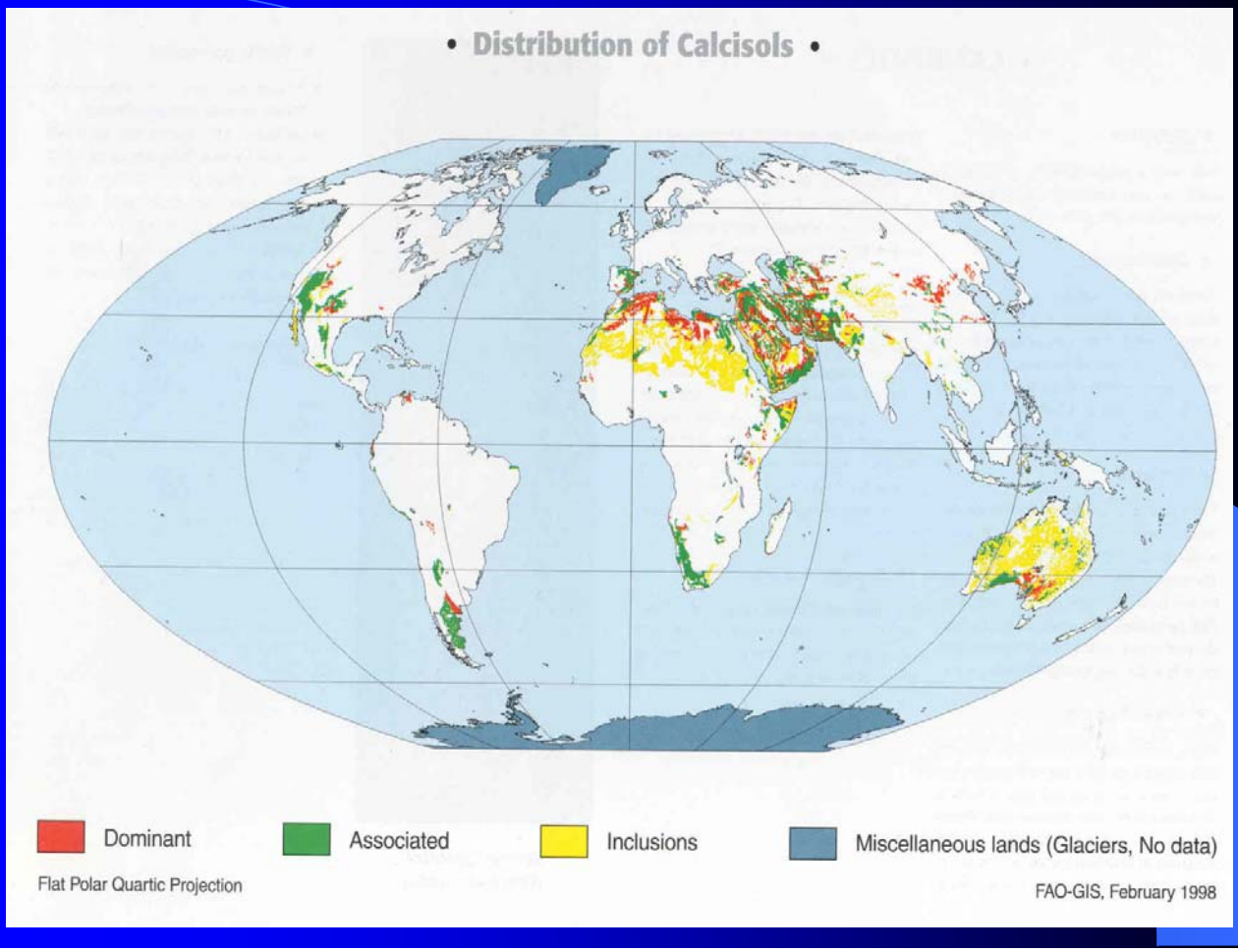
Soils with accumulation of secondary calcium carbonate ($CaCO_3$), forming *calcic* or *petro-calcic* horizons:

- Calcic: > 15% calcium carbonate and > 5% secondary carbonates
- Petrocalcic: hardened calcium carbonate bank

Calcisols

Physical properties:

- Good water-holding capacity
- Prone to slaking and crusting
- Petrocalcic horizons hamper root penetration, unless they are fractured



Solonchaks

Soils with accumulation of salts more soluble than gypsum *(salic horizon)*.

Salinity is measured as EC (mS cm^{-1}) or total salt content (weight %). It affects plant growth as osmotic pressure causes toxic and water stress effects.

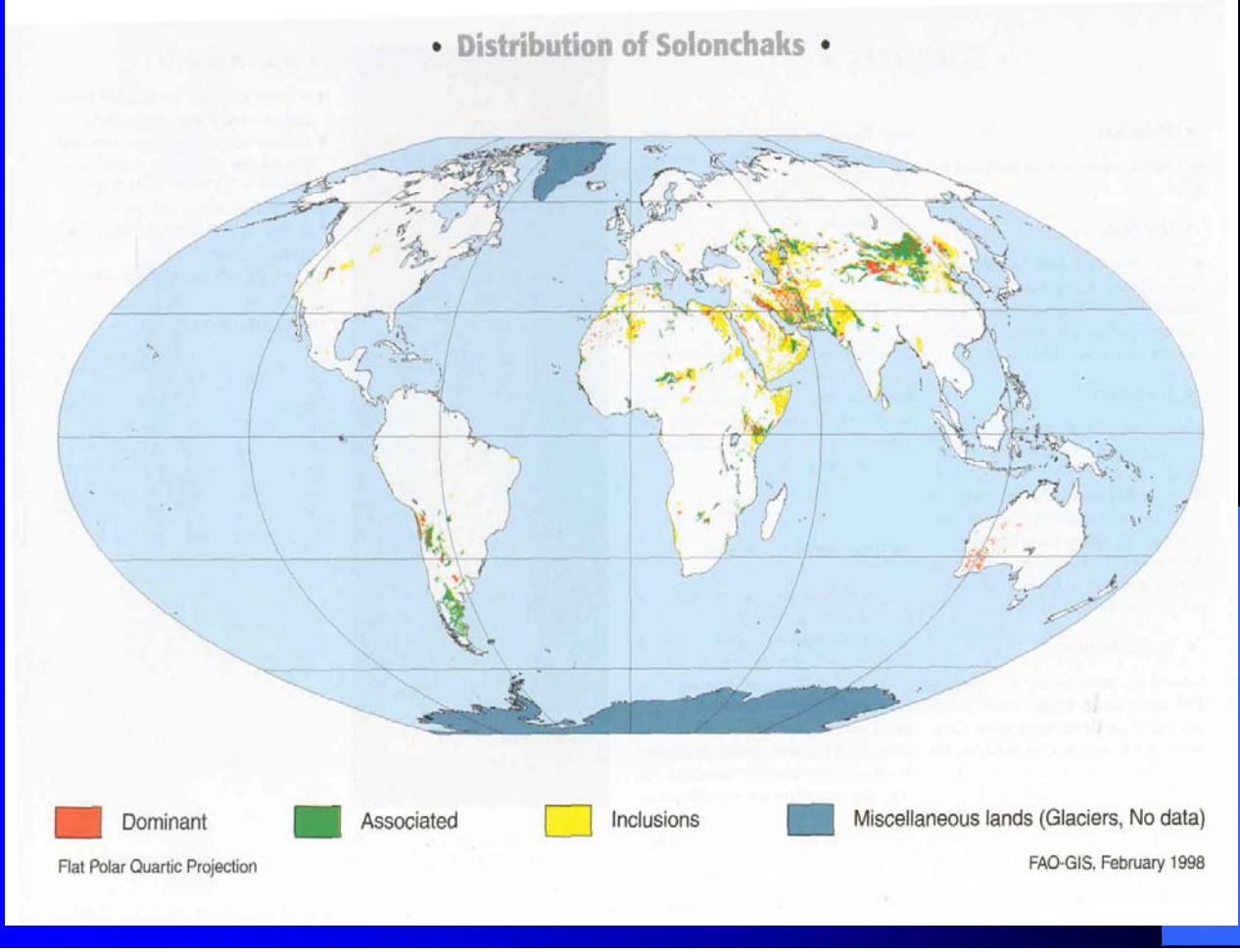
Salinity also affects the structural stability as presence of salts induces dispersion of the clay particles.

Solonchaks

Physical properties:

- Prone to crusting and erosion, because of the dispersion effect of salts

A special type is the *puffed* Solonchak, a soil with a *night – day* rhythm of sodium-sulphate dissolution and accumulation.


• Distribution of Solonchaks •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

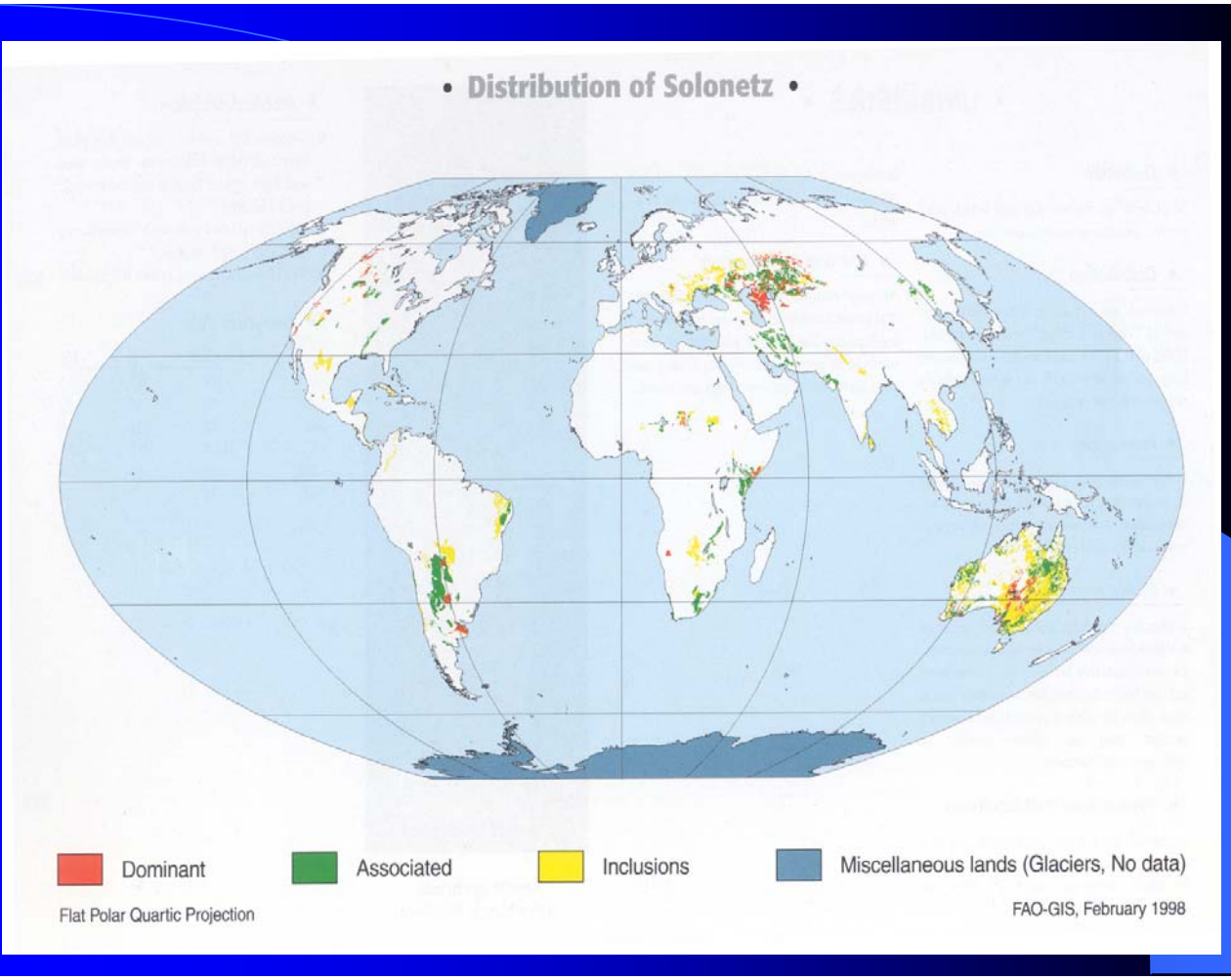
Solonetz

Soils with a high amount of exchangeable sodium (> 15% of the adsorbed cations), accumulated in the subsoil in a so-called *natric* horizon.

Solonetz

Physical properties:

- Dispersion of clay and humus
- Clogging of pores
- Slowly permeable subsoil with high bulk density
- Waterlogging


• Distribution of Solonetz •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Soils conditioned by steppe climates

Characteristic for soils of the steppes is the accumulation and rapid mineralization of large amounts of organic matter under influence of high, soil faunal activity, and accumulation of variable amounts of carbonates and gypsum.

Three typical soils are recognized, all characterized by a *mollic* horizon:

- *Chernozems*
- *Kastanozems*
- *Phaeozems*

Chernozems

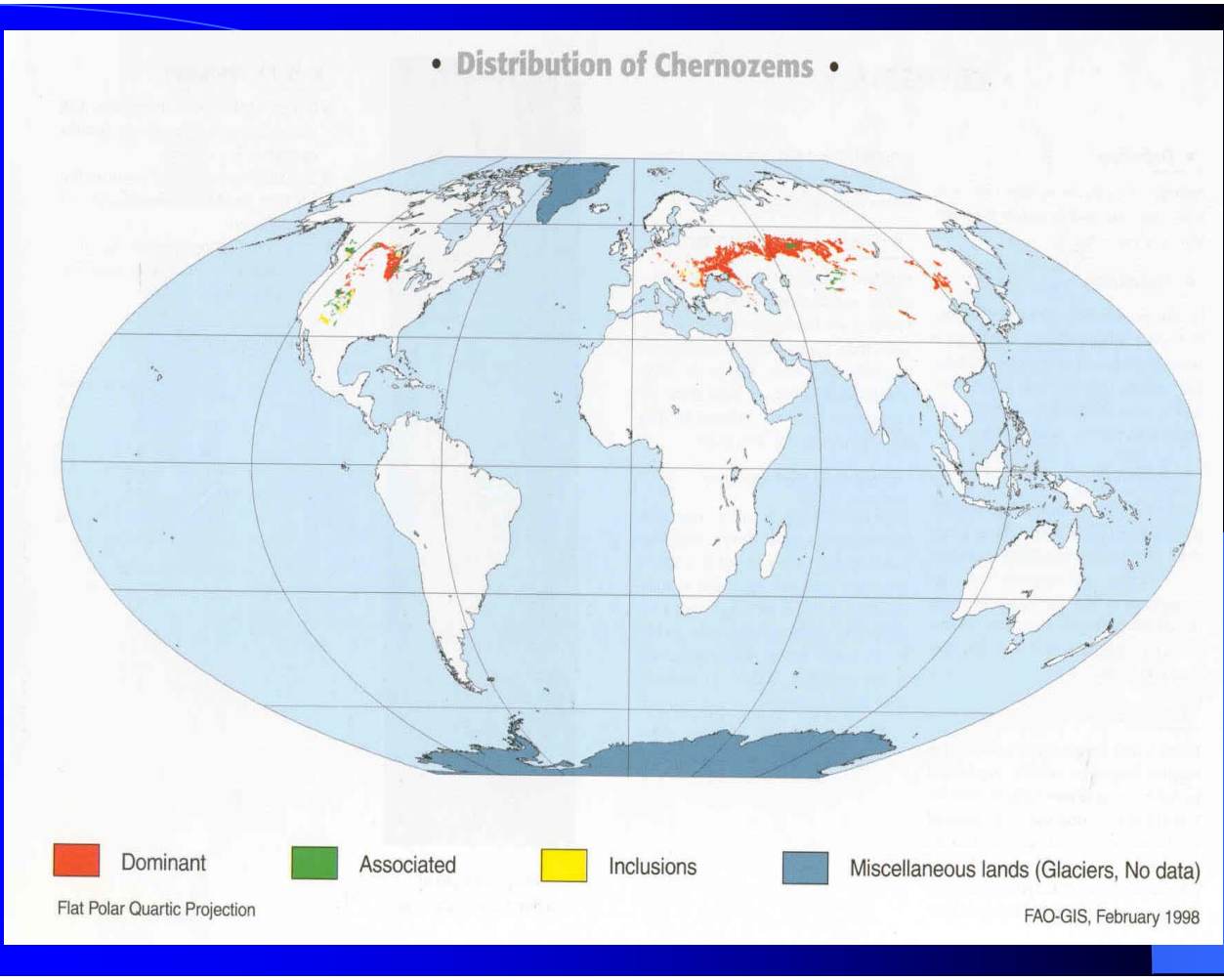
Soils of the tall-grass steppes, with a thick, very dark brown or black, humus-rich surface horizon and accumulation of carbonates within 2 m from the surface.

Chernozems form the central concept of the *steppe soils*, bordered by *Kastanozems* on the drier side and *Phaeozems* on the wetter side.

Chernozems

Physical properties:

- High porosity (between 50 and 60 volume percentage)
- Good moisture holding capacity (20 volume percent or more AWC)
- Stable micro-aggregate structure
- Under cultivation, vulnerable to wind erosion when dry


• Distribution of Chernozems •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Kastanozems

Soils of the short-grass steppes, chestnut brown in colour, with accumulation of calcium carbonate or gypsum close to the surface.

Surface horizon not as thick and dark coloured as in Chernozems.

Physical properties are comparable but slightly less favourable; in particular their vulnerability to wind erosion when dry.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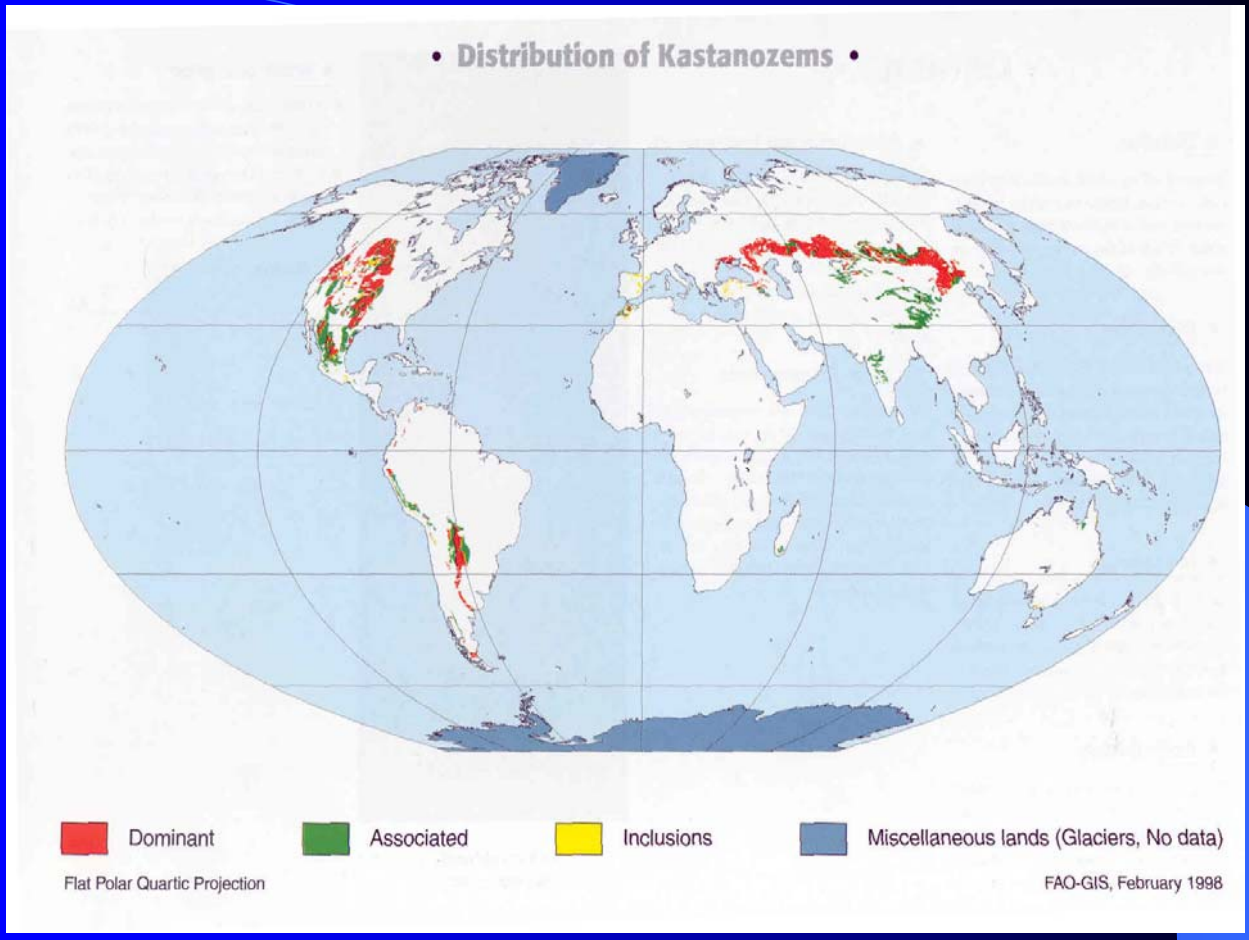


Phaeozems

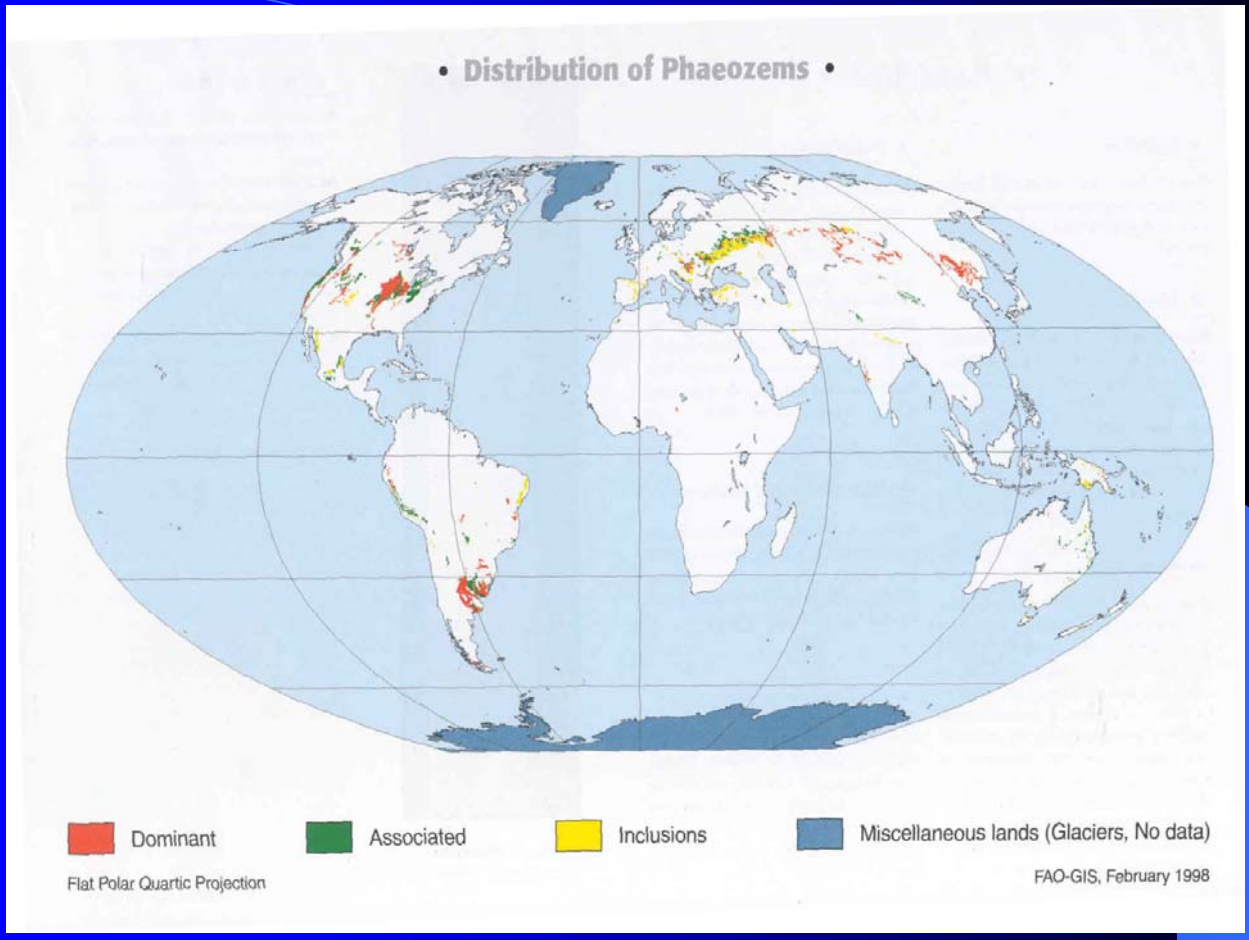
Soils of the wetter steppes with a dark brown, humus-rich and base-satured surface horizon, but lacking carbonates within 2 m.

Carbonate removal and accumulation of humus are the two main processes forming *Phaeozems*.

Phaeozems

Physical properties:

- Good moisture holding capacity
- Stable micro-aggregate structure
- Not very prone to erosion, even on slopes



Soils conditioned by temperate climates

- ***Luvisols*** *(soils with an* ***argic*** *horizon)*
- ***Albeluvisols*** *(soils with* ***albeluvic tonguing*** *and an* ***argic*** *horizon)*
- ***Podzols*** *(soils with a* ***spodic*** *horizon)*
- ***Planosols*** *(soils with an* ***abrupt textural change****)*
- ***Umbrisols*** *(soils with an* ***umbric*** *horizon)*

Luvisols

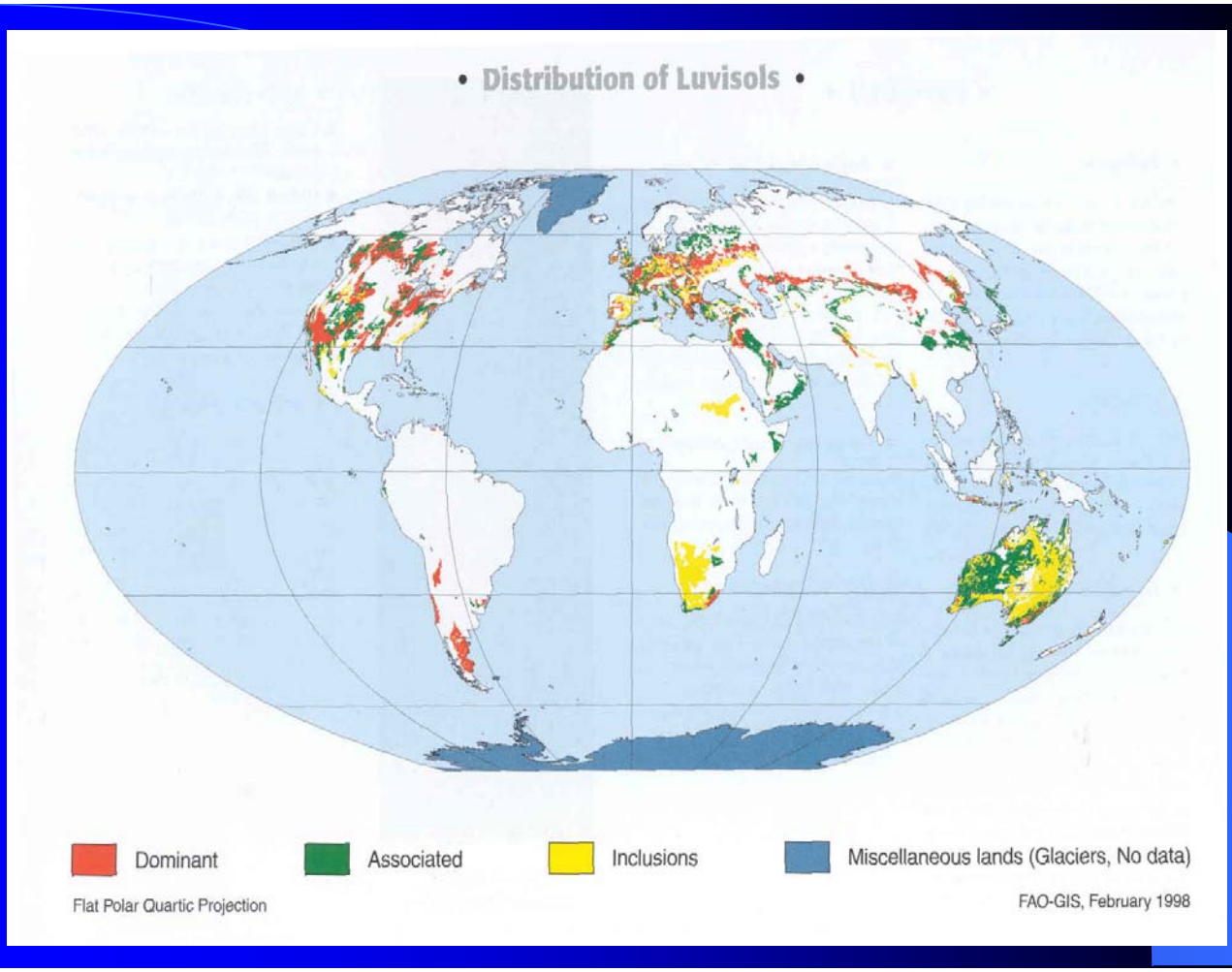
Moderately leached soils with

- Pronounced increase in clay with depth *(argic horizon)*
- Slightly acid to neutral soil reaction
- Moderate to high activity clay and high base saturation

Luvisols

Physical properties:

- Porous and well-aerated topsoil
- Moderate to high available water content
- Subsoil porosity decreases over time due to clay illuviation, reducing water infiltration and inducing water stagnation
- When on slopes, prone to topsoil erosion


• Distribution of Luvisols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Albeluvisols

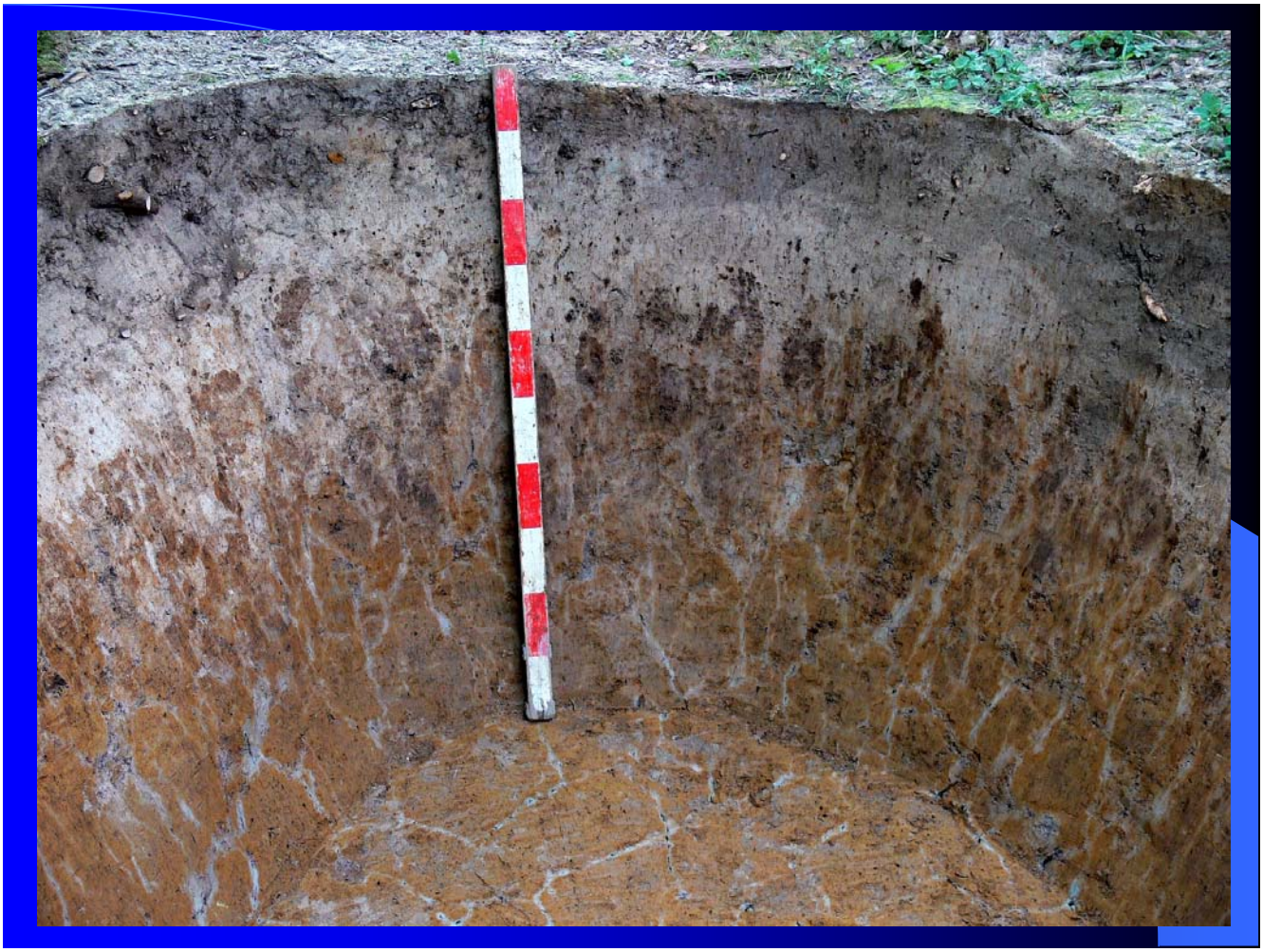
Soils with a pronounced *albic* (white, clay-depleted) horizon penetrating into an underlying *argic* (clay-enriched) horizon.

Considered to be *polycyclic* soils; soil starts forming under periglacial conditions and continues its development under subsequent warmer and wetter climates.

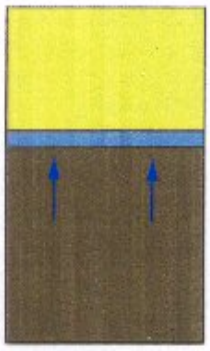
Albeluvisols

Physical properties:

- Poorly structured topsoil
- Dense subsoil, often inpenetrable for roots (*closed box system*)
- Water stagnation on dense subsoil
- Restricted water movement

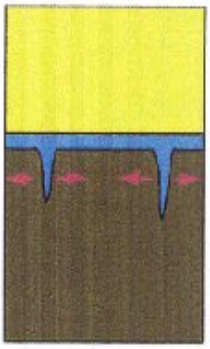


Formation of a fragipan (Dryas period, +/-13500 BD)



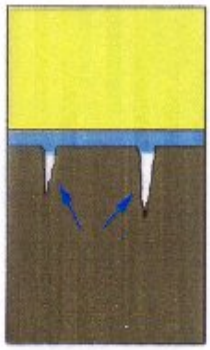
1. permafrost layer with low water pressure

water moves upward



3. Growth of ice wedges

Lateral compaction

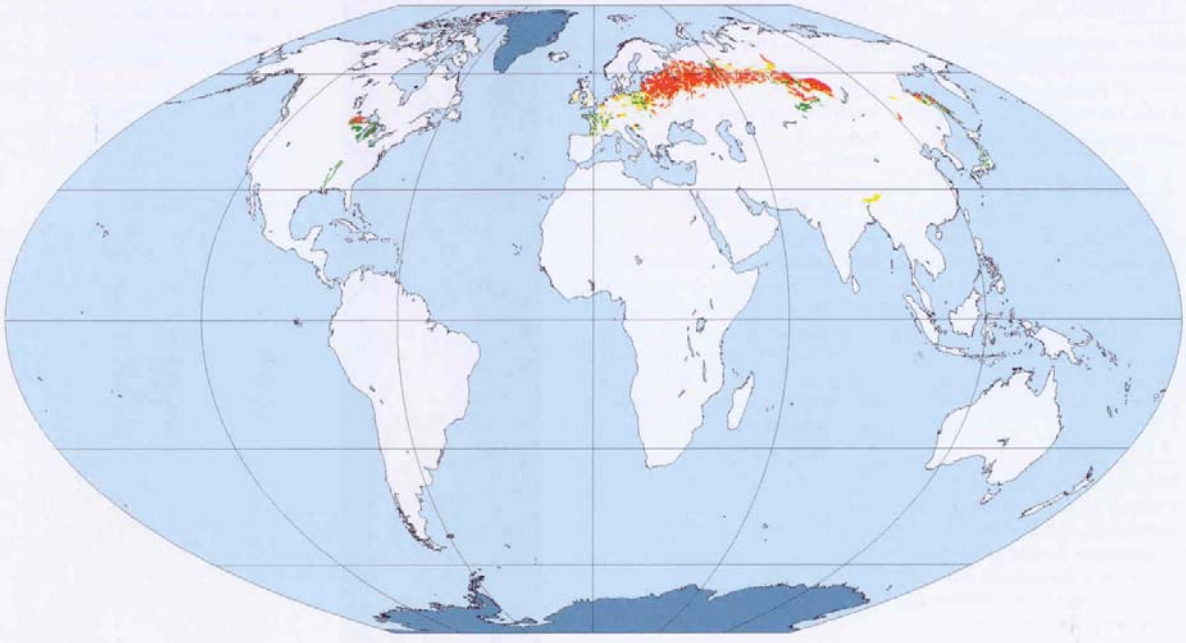


2. drying proces results in cracking

water moves towards cracks and freezes

4. after melting cracks are filled with top material

• Distribution of Albeluvisols •



Dominant | Associated | Inclusions | Miscellaneous lands (Glaciers, No data)

Flat Polar Quartic Projection

FAO-GIS, February 1998

Podzols

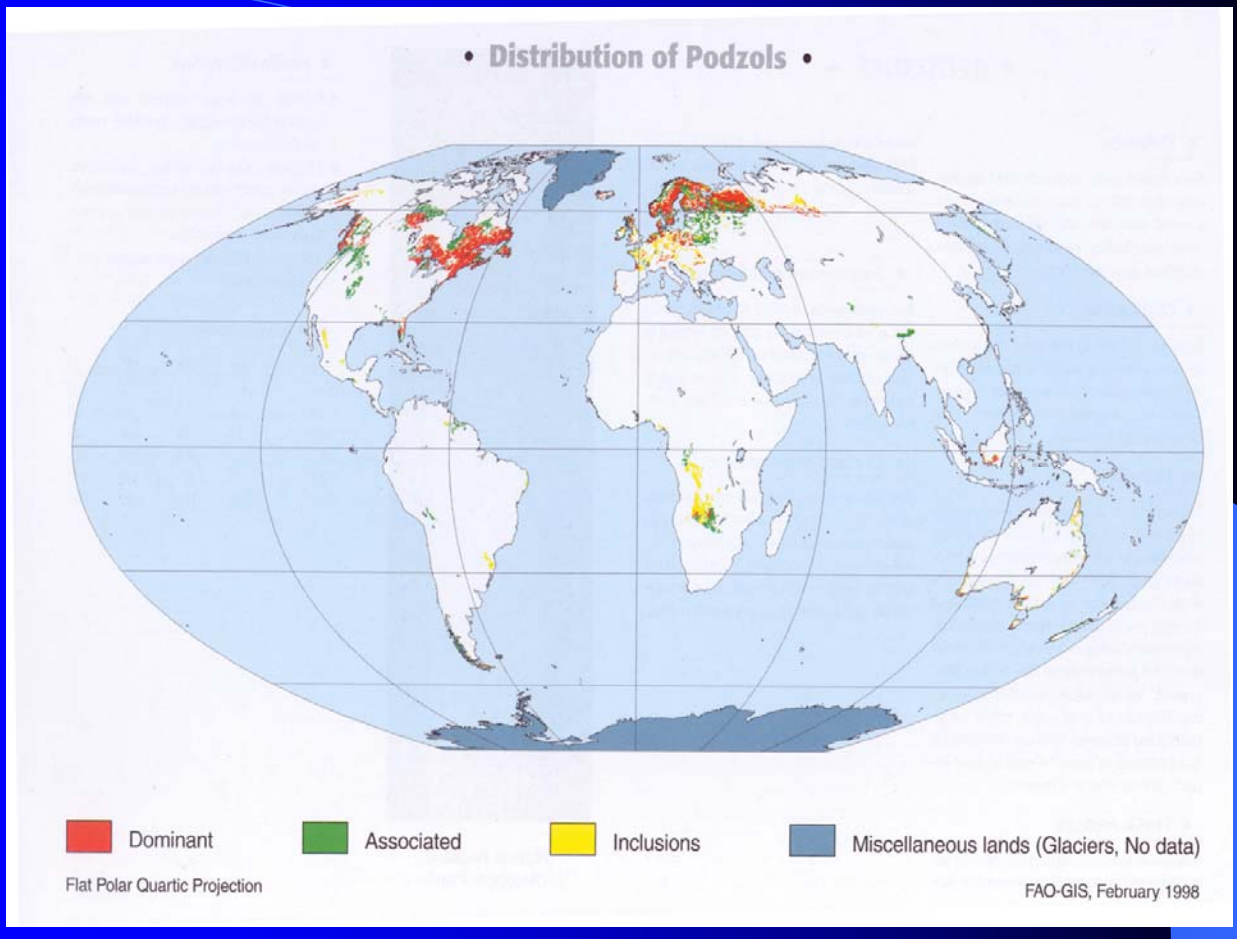
Soils in siliceous parent materials formed by the process of *cheluviation*, i.e. movement of soluble metal-humus complexes (chelates) downwards.

The process leads to an ash-grey layer near the surface and a brownish to blackish illuvial layer below.

Podzols

Physical properties:

- Sandy texture
- Weak aggregation into structural elements
- Low water-holding capacity
- Illuviation may lead to very dense subsoil (*ortstein*) or iron banks and, eventually, to water stagnation


• Distribution of Podzols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Planosols

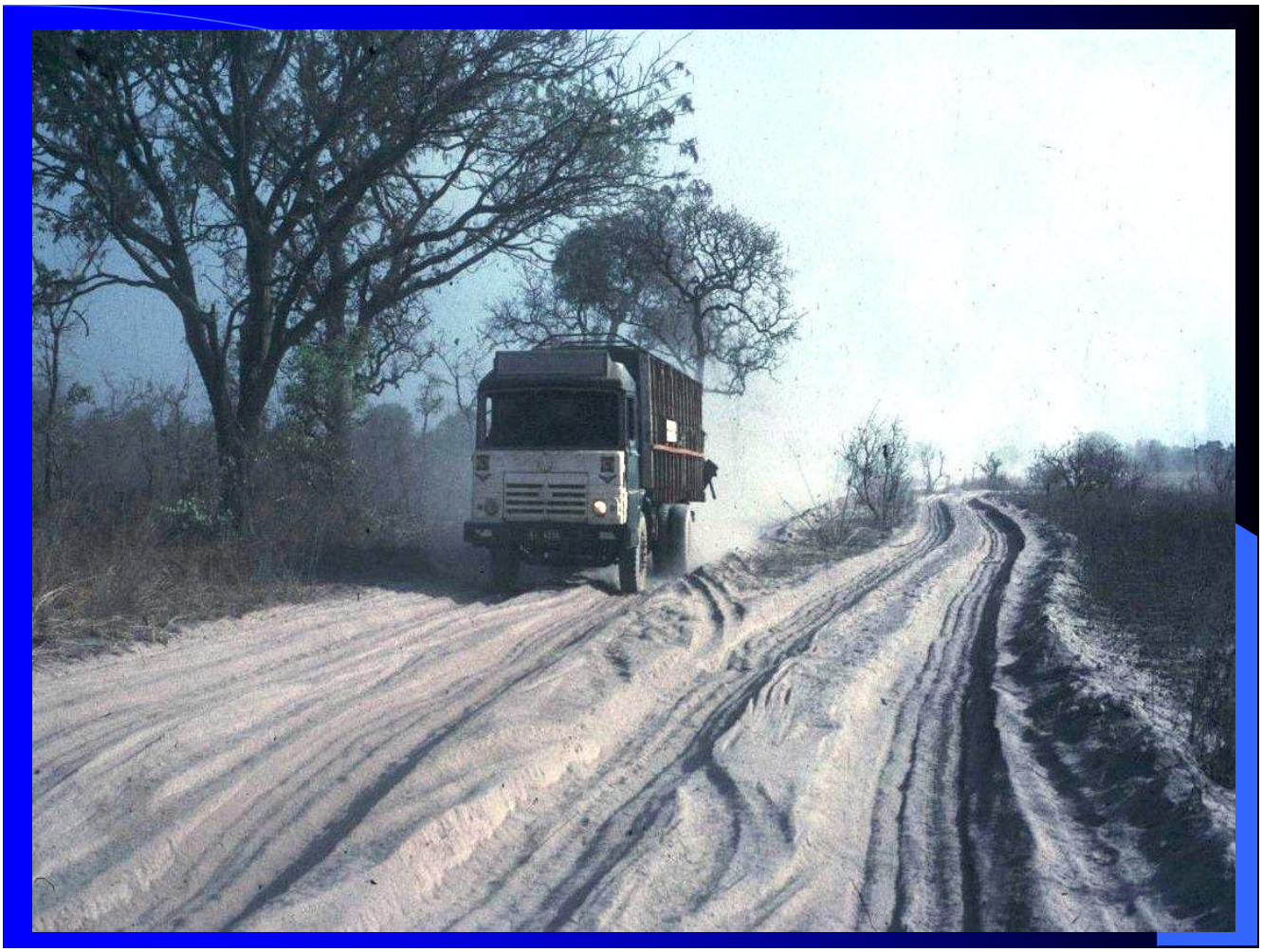
Soils with an abrupt textural change and evidence of water stagnation, i.e. a sandy or silty topsoil overlying a clayey subsoil with mottles or iron-manganese concretions just above and below the abrupt transition.

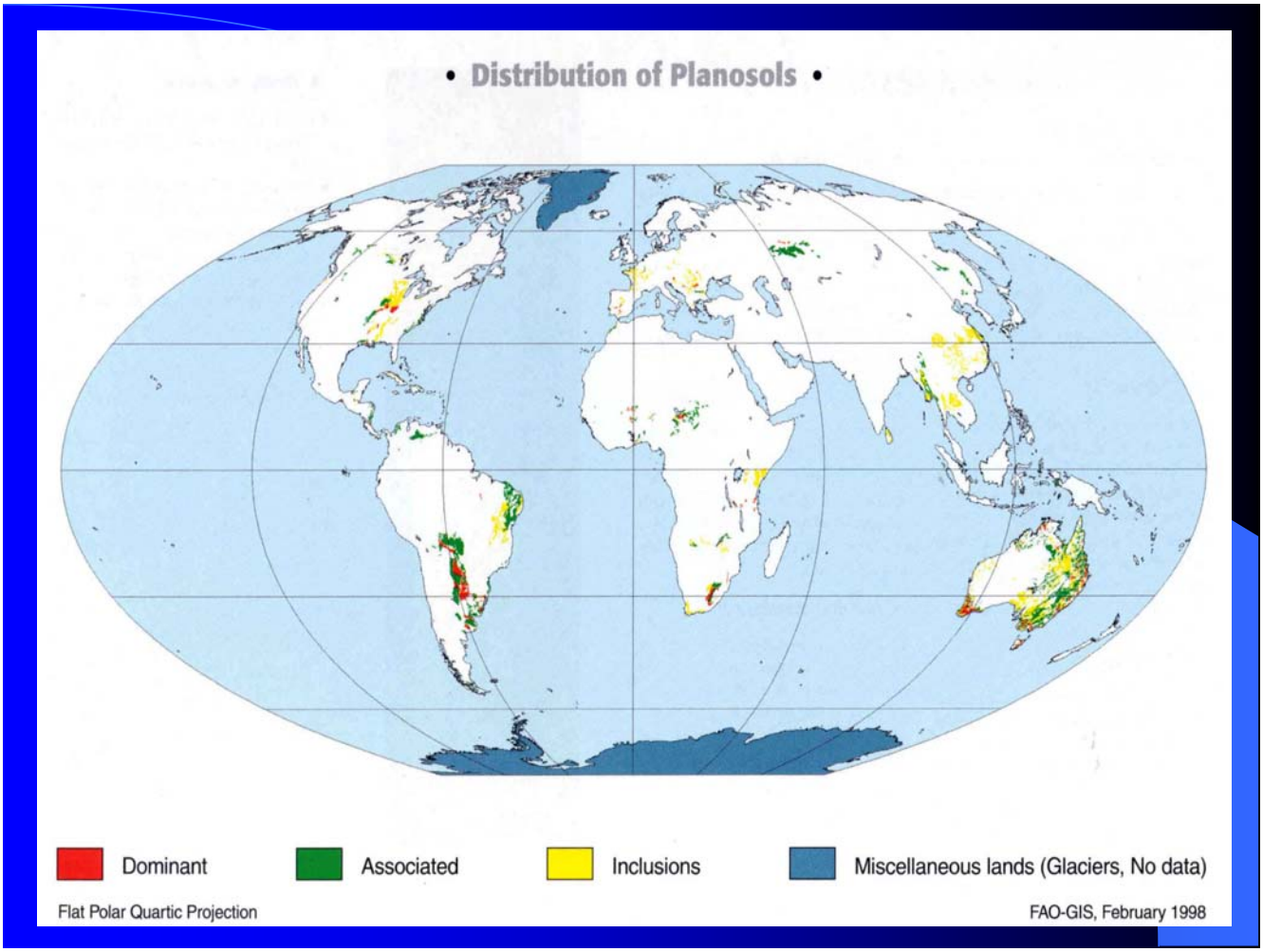
Also known as *duplex soils*.

Planosols

Physical properties:

- Water stagnation during part of the year
- Very weakly expressed and unstable structural elements in the upper part of the soil
- Compact subsoil, impairing root penetration





Umbrisols

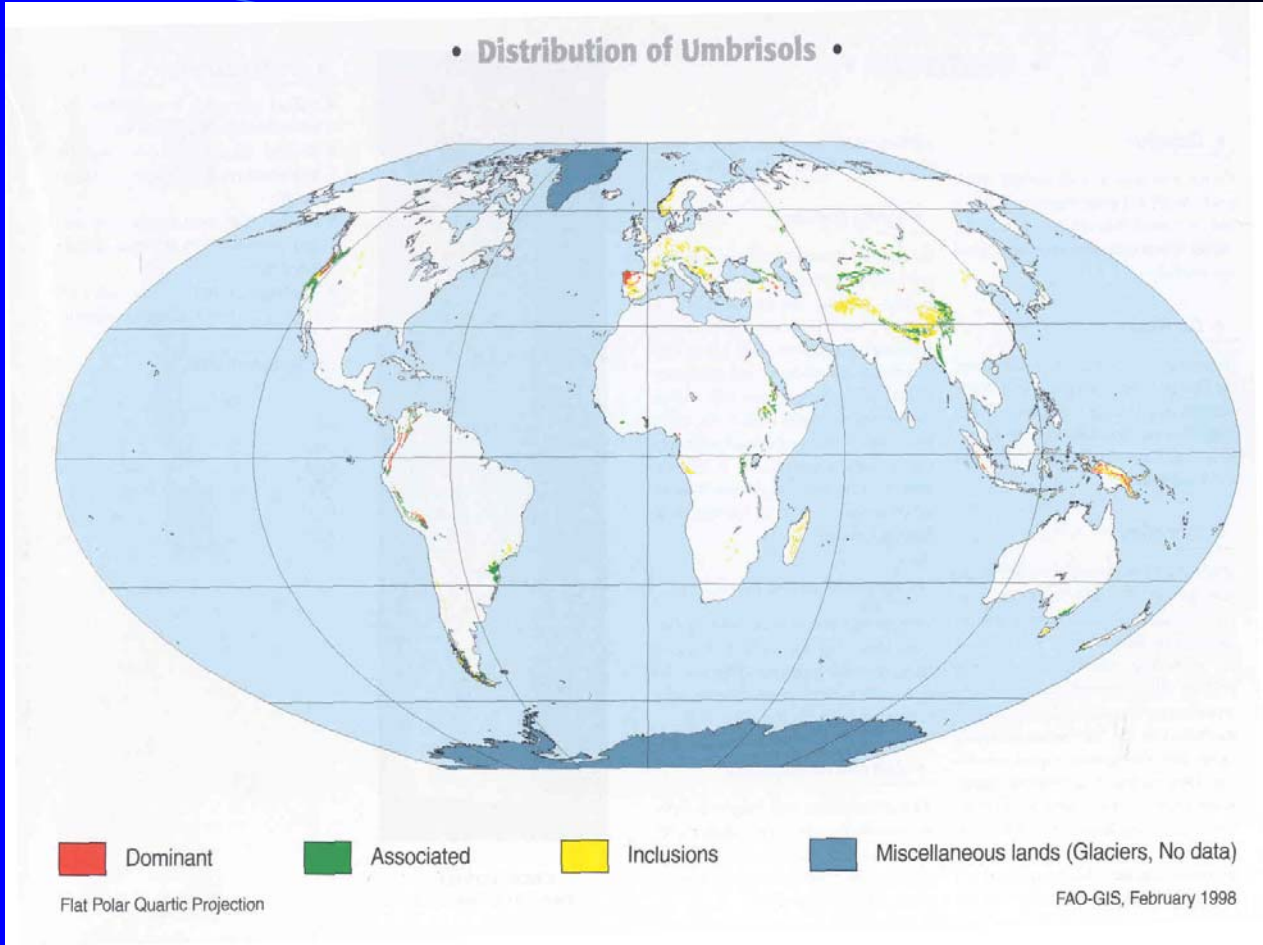
Soils with an acid, dark brown, humus-rich but base-desatured surface horizon.

Umbrisols are the strongly leached counterparts of the *Phaeozems*, mainly occurring over siliceous parent materials and in wet climates.

Umbrisols

Physical properties:

- Well-drained
- Well-aerated
- Prone to erosion if on slopes


• Distribution of Umbrisols •
Dominant
Associated
Inclusions
Miscellaneous lands (Glaciers, No data)
Flat Polar Quartic Projection
FAO-GIS, February 1998

Soils conditioned by cold climates

Cryosols *(soils with evidence of frost churning or cryotubation)*

Cryosols

Soils with evidence of freezing and thawing, such as frost heave of coarse materials, cryoturbation and mechanical weathering.

Cryotubation leads to irregular or broken soil horizons; frost heave leads to sorting and polygon formation.

Cryosols

Physical properties:

- Water-saturation during the thawing season; then poorly trafficable
- Occurrence of variable amounts of ice in the subsoil
- Thawing of ice may lead to an irragular land surface *(thermokarst)*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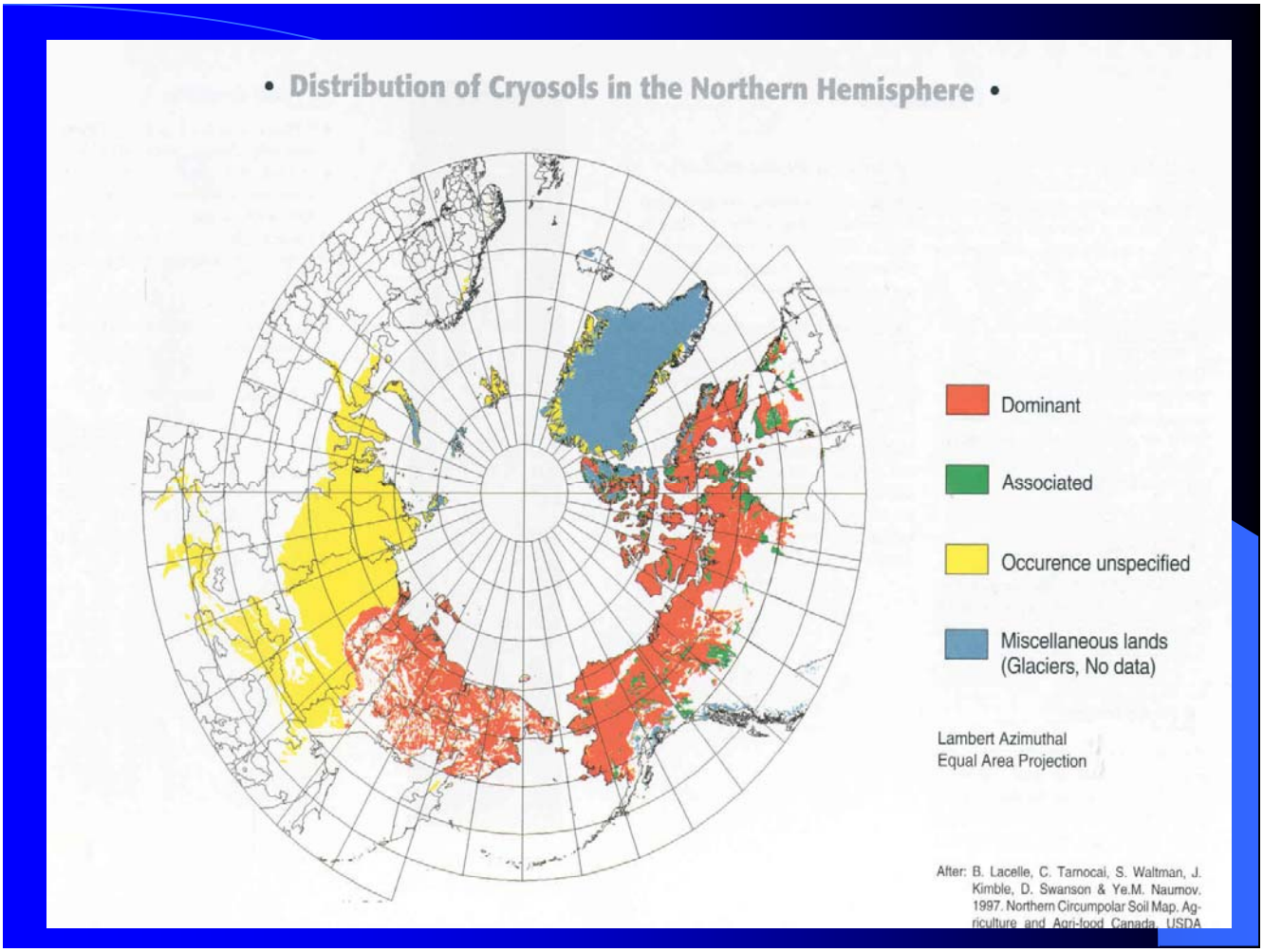


Man-made soils

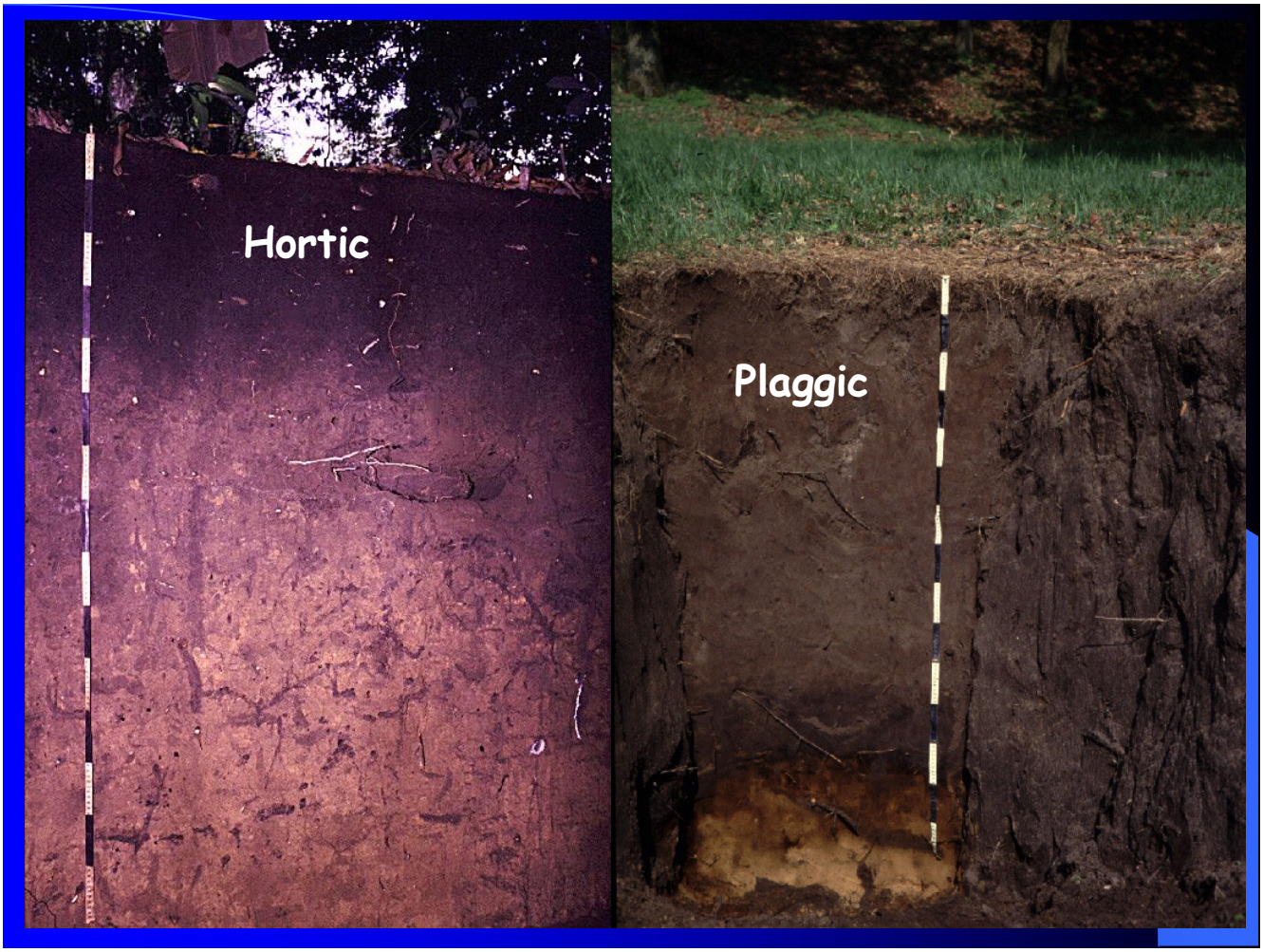
- ***Anthrosols*** *(man-made agricultural soils)*
- ***Technosols*** *(soils with large amounts of man-made material or artefacts)*

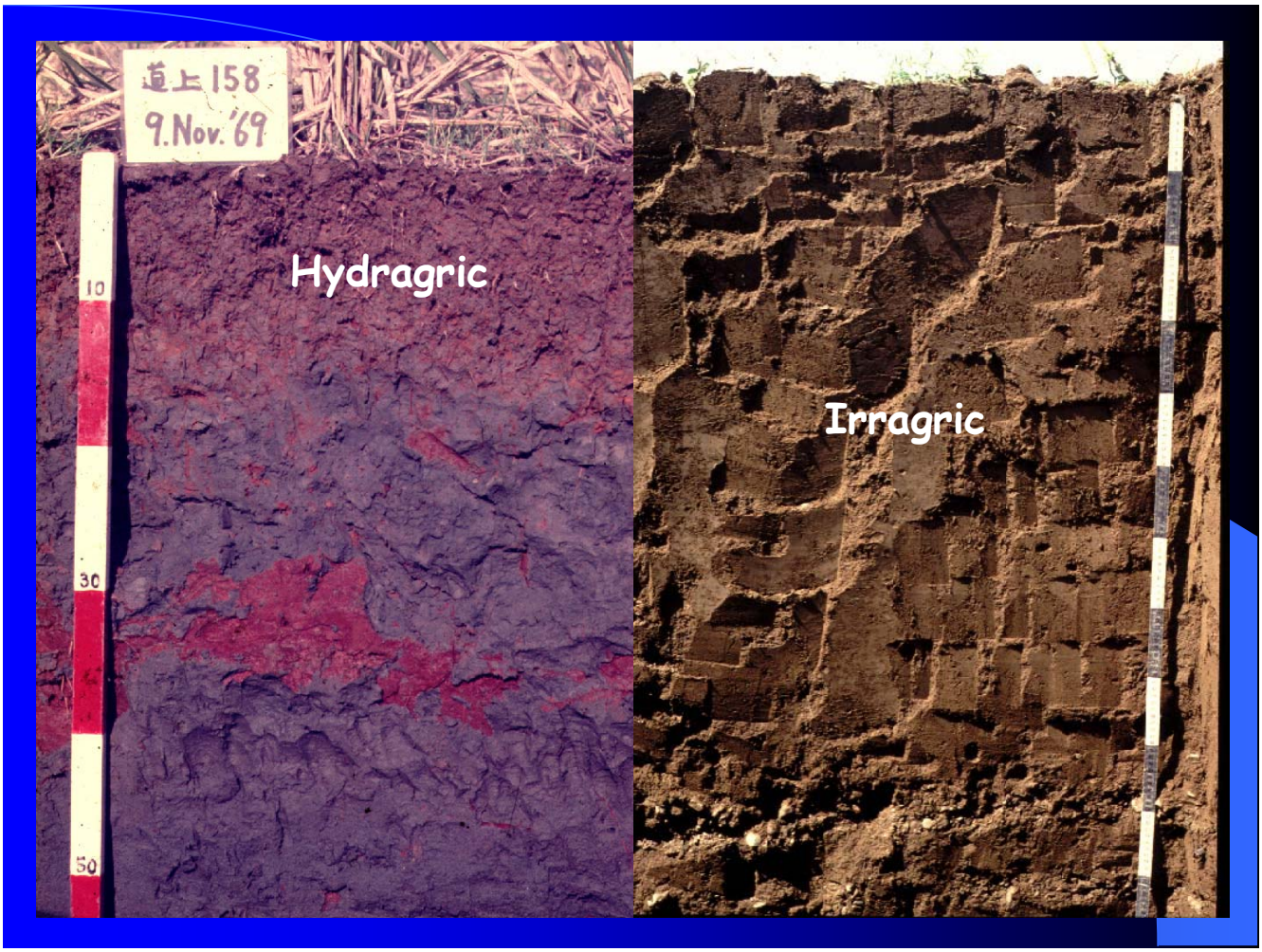
Anthrosols

Soils under long-time cultivation, modified to the extent that the original soil has been completely changed

Anthrosols

- ***Hortic:*** long-continued deep cultivation, intensive fertilization or application of organic residues
- ***Plaggic:*** long-continued addition of farmyard manure mixed with sods
- ***Hydragric:*** long-continued paddy rice cultivation
- ***Irragric:*** long-continued irrigation with sediment-rich water


Hortic
Plaggic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Hydragric
10
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Irragric

Anthrosols

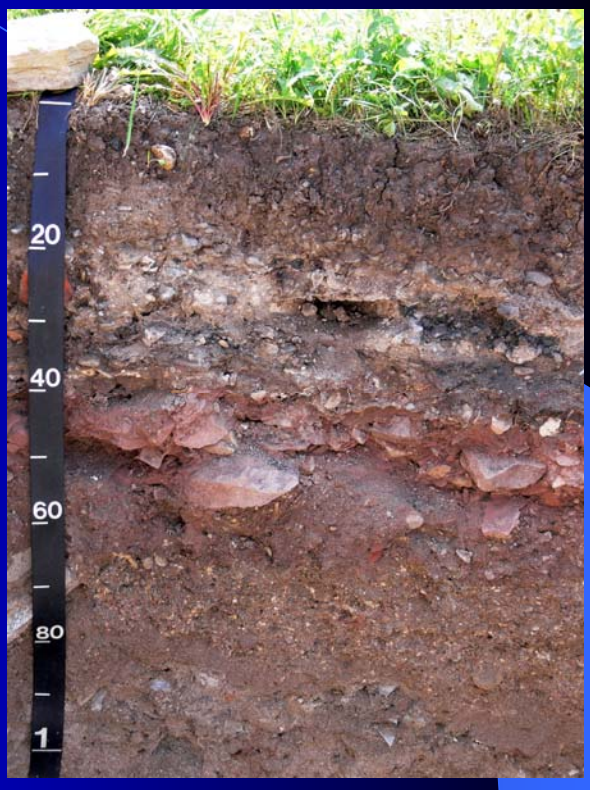
Physical properties:

- *Hortic and Plaggic*
  - Improved soil structure
  - Improved water-holding capacity
  - Raising of the land surface *(Plaggic only)*
- *Hydragric*
  - Structureless topsoil
  - Development of a slowly permeable plough pan
- *Irragric*
  - Increased biological activity
  - Uniform texture, usually silty
  - Raising of the land surface

Technosols

Soils with large amounts of man-made products, such as industrial waste, mine spoils, sewage sludge, urban rubble, hydrocarbons and garbage.

Included are *sealed soils* such as under cities, roads and highways, and glasshouse complexes.



Technosols

Technosols have a wide range of physical properties:

- Highly variable bulk density (0.4 - 2.1 kg/dm^3)
- Variable degree of hardening (from very loose to extremely indurated)
- Very specific hydrological regimes
- Large amounts of coarse and inert material


01
02
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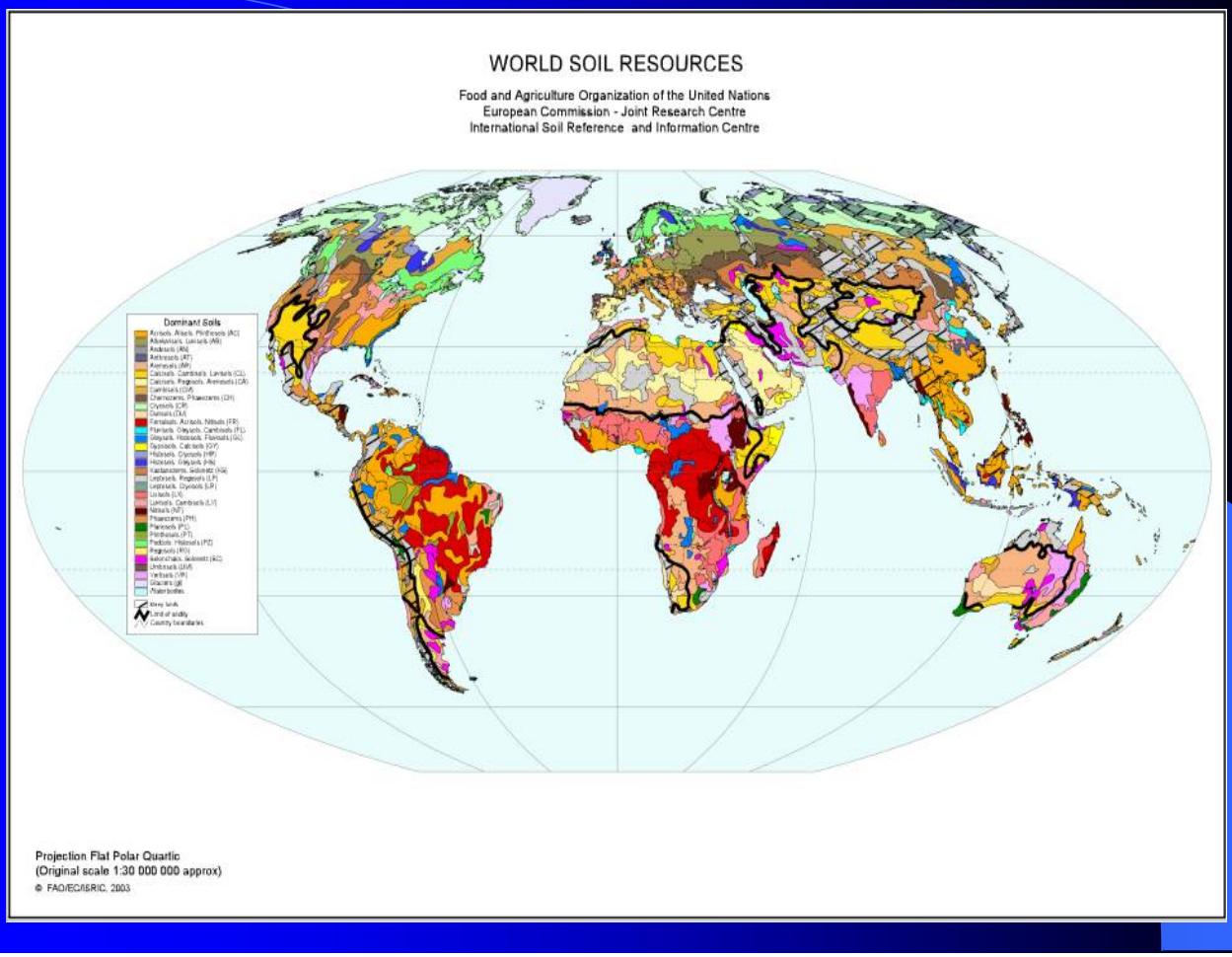
Heavy metal content (mg/kg) 0 - 10 cm

	Act. Cont.	Max. All. Lim.
Cd	8	8
Cu	3300	125
Ni	495	100
Pb	1150	500
Zn	5300	400



http://www.isric.org

ftp://ftp.fao.org/agl/agll/docs/wsrr103e.pdf

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