Package ‘soilKey’

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Type Package

Title Automated Soil Profile Classification per 'WRB' 2022, 'SiBCS' 5 and 'USDA' Soil Taxonomy 13

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Description Implements deterministic classification keys for the World Reference Base for Soil Resources ('WRB') 2022, 4th edition (IUSS Working Group WRB, 2022, ISBN:979-8-9862451-1-9), the Brazilian System of Soil Classification ('SiBCS') 5th edition (Santos et al., 2018, ISBN:978-85-7035-800-4) and the United States Department of Agriculture ('USDA') Soil Taxonomy 13th edition (Soil Survey Staff, 2022, <https://www.nrcs.usda.gov/resources/guides-and-instructions/keys-to-soil-taxonomy>).
Provides a unified profile representation with explicit per-attribute provenance, multimodal extraction from field reports and photos via vision-language models (VLM), spatial priors from 'SoilGrids' (Poggio et al., 2021, <doi:10.5194/soil-7-217-2021>) and national soil maps, and gap-filling of soil attributes from visible-near-infrared (Vis-NIR) or mid-infrared (MIR) spectra via the Open Soil Spectral Library ('OSSL'; Safanelli et al., 2025, <doi:10.7717/peerj.18908>). The taxonomic key itself is never delegated to a large language model (LLM); LLMs are restricted to schema-validated extraction. Each classification result reports a key trace, a provenance-aware evidence grade, and ambiguities that further measurement would resolve.

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URL https://github.com/HugoMachadoRodrigues/soilKey, https://hugomachadorodrigues.github.io/soilKey/

BugReports https://github.com/HugoMachadoRodrigues/soilKey/issues

Encoding UTF-8

LazyData true

RoxygenNote 7.3.3

Depends R (>= 4.1)

Imports R6, data.table, yaml, cli, rlang, withr

Suggests aqp, SoilTaxonomy, mpspline2, terra, foreign, sf, chromote, munsellinterpol, pls, prospectr, resemble, ellmer, httr, jsonlite, jsonvalidate, pdftools, magick, shiny, DT, DBI, RSQLite, testthat (>= 3.0.0), knitr, rmarkdown

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NeedsCompilation no

Author Hugo Rodrigues [aut, cre] (ORCID: <https://orcid.org/0000-0002-8070-8126>)

Maintainer Hugo Rodrigues <rodrigues.machado.hugo@gmail.com>

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---

abrupt_textural_difference *Abrupt textural difference (WRB 2022 Ch 3.2.1)*

Description

Sharp clay-content increase between two superimposed mineral layers meeting all of:

- underlying clay \>= 15% AND thickness \>= 7.5 cm;
- underlying starts \>= 10 cm below mineral soil surface;
- underlying has, vs overlying: 2x clay if overlying < 20%, OR \>= 20pp (absolute) more clay if overlying \>= 20%;
- transitional layer, if any, \<= 2 cm.

v0.3.3 enforces criteria 1, 2, 3. The transitional-layer check is deferred (the canonical horizon schema does not carry a "transitional" marker; it can be added later via boundary_distinctness inspection).

Usage

```
abrupt_textural_difference(pedon)
```

Arguments

pedon	A PedonRecord.

---

acric_andisol_usda *Acric Subgroup helper (Andisols Acrudoxic / Acraquoxic / Acrustoxic / etc.)*

Description

Pass when the sum of extractable bases (NH4OAc) plus 1N KCl-Al is < 2.0 cmol(+)/kg in fine earth, in a 30+ cm layer between 25 and 100 cm. v0.8 proxy: ECEC <= 2.0 in B horizons.

Usage

```
acric_andisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

acric_oxisol_usda *Acric Oxisol Suborder helper (Acroperox/Acrudox/Acrustox/Acraquox) Pass when oxic or kandic horizon has ECEC < 1.5 cmol/kg clay AND pH (KCl) >= 5.0.*

Description

Acric Oxisol Suborder helper (Acroperox/Acrudox/Acrustox/Acraquox) Pass when oxic or kandic horizon has ECEC < 1.5 cmol/kg clay AND pH (KCl) >= 5.0.

Usage

```
acric_oxisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

acrisol *Acrisol RSG diagnostic (WRB 2022)*

Description

Tests whether a profile satisfies the Acrisol RSG criteria: an argic horizon with low-activity clay (CEC < 24 cmol_c/kg clay) AND low base saturation (BS < 50%) within at least one argic layer.

Usage

```
acrisol(pedon, max_cec = 24, max_bs = 50)
```

Arguments

pedon	A PedonRecord.
max_cec	Maximum CEC per kg clay (default 24).
max_bs	Maximum base saturation % (default 50).

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 5, Acrisols.

`aeolic_material` *Aeolic material (WRB 2022 Ch 3.3.1)*

Description

Wind-deposited material in the upper 20 cm: rounded matt-surfaced sand grains OR aeroturbation features, AND < 1% SOC in the upper 10 cm. v0.3.3 detects via `rock_origin == "aeolian"` OR `layer_origin == "aeolic"`.

Usage

```
aeolic_material(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`aeric_oxisol_usda` *Aeric Subgroup (for Oxisols Aquox) – chroma-3 below epipedon Already defined for Aquods; here we add Oxisol-specific variant (any 10+ cm horizon below A with chroma >= 3 in 50%+ peds).*

Description

Aeric Subgroup (for Oxisols Aquox) – chroma-3 below epipedon Already defined for Aquods; here we add Oxisol-specific variant (any 10+ cm horizon below A with chroma >= 3 in 50%+ peds).

Usage

```
aeric_oxisol_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`aeric_subgroup_usda` *Aeric Subgroup helper (Aquods) Pass when ochric epipedon is present (vs. histic/umbric/etc).*

Description

Aeric Subgroup helper (Aquods) Pass when ochric epipedon is present (vs. histic/umbric/etc).

Usage

```
aeric_subgroup_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

`albaquult_qualifying_usda` *Albic-over-argillic qualifying (Albaquults) Pass when albic horizon overlies an argillic horizon directly.*

Description

Albic-over-argillic qualifying (Albaquults) Pass when albic horizon overlies an argillic horizon directly.

Usage

```
albaquult_qualifying_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

albeluvic_glossae — *Albeluvic glossae (WRB 2022 Ch 3.2.2)*

Description

Tongues of bleached, coarser-textured material penetrating an argic horizon. v0.3.3 detects via designation pattern `glossic|albeluvic` on a layer that overlies an argic-horizon-passing layer.

Usage

```
albeluvic_glossae(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

albic — *Albic horizon (WRB 2022)*

Description

A bleached eluvial horizon – claric material that has lost iron oxides and/or organic matter due to clay migration, podzolization, or redox under stagnant water. Diagnostic for parts of Podzols, Retisols and Planosols qualifiers.

Usage

```
albic(pedon, min_thickness = 1)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness in cm (default 1, per WRB 2022). The albic horizon has no canonical thickness gate; we keep a token min so that fully-NA layers don't pass.

Details

Sub-tests:

- `test_claric_munsell` – Munsell criteria of claric material (Ch 3.3.4).

Designation pattern `E` or `Eg` also serves as positive evidence when Munsell columns are missing (proxy path).

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Ch 3.1 – Albic horizon.

---

albic_horizon_usda *Albic horizon (USDA, KST 13ed Ch 3)*

Description

Pass when an albic horizon (light-colored, eluvial; chroma <= 2, value >= 4) >= 1 cm thick is present. Delegates to WRB albic diagnostic.

Usage

```
albic_horizon_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

---

albic_subgroup_usda *Albic Subgroup helper (Albaquultic / Albaquic)*

Description

Albic Subgroup helper (Albaquultic / Albaquic)

Usage

```
albic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

alboll_qualifying_usda

Albolls qualifier: mollic + albic + argillic.

Description

Albolls qualifier: mollic + albic + argillic.

Usage

```
alboll_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

alfic_subgroup_usda

Alfic Subgroup helper (Spodosols): argillic or kandic with BS >= 35%

Description

Alfic Subgroup helper (Spodosols): argillic or kandic with BS >= 35%

Usage

```
alfic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

alfisol_qualifying_usda

Alfisol Order qualifier Pass when argillic OR kandic horizon present + BS >= 35% in some part.

Description

Alfisol Order qualifier Pass when argillic OR kandic horizon present + BS >= 35% in some part.

Usage

```
alfisol_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`alfisol_usda` *Alfisols (USDA Cap 5): argillic/kandic/natric horizon + base saturation >= 35% at the implicit reference depth.*

Description

Alfisols (USDA Cap 5): argillic/kandic/natric horizon + base saturation >= 35% at the implicit reference depth.

Usage

```
alfisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`alic_andisol_usda` *Alic Subgroup helper (Andisols) Pass when al_kcl_cmol > 2.0 in a 10+ cm layer between 25 and 50 cm.*

Description

Alic Subgroup helper (Andisols) Pass when al_kcl_cmol > 2.0 in a 10+ cm layer between 25 and 50 cm.

Usage

```
alic_andisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

alisol — *Alisol RSG diagnostic (WRB 2022)*

Description

argic + CEC >= 24 cmol_c/kg clay + Al saturation >= 50%.

Usage

```
alisol(pedon, min_cec = 24, min_al_sat = 50)
```

Arguments

pedon	A PedonRecord.
min_cec	Minimum CEC per kg clay (default 24).
min_al_sat	Minimum Al saturation % (default 50).

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 5, Alisols.

al_rich_spodic_usda — *Aluminum-rich spodic helper (Alaquods, Alorthods, KST Ch 14)*

Description

Pass when the spodic horizon has < 0.10% Fe (oxalate) in 75%+ of layers, OR Al >= 3 * Fe in 75%+ of layers (Alaquods only).

Usage

```
al_rich_spodic_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

`andic_properties` *Andic properties (WRB 2022)*

Description

Tests for the andic property complex – volcanic-ash-derived allophanic / imogolitic / Al-humus material. Diagnostic of Andosols. Two alternative qualifying paths per WRB 2022 Ch 3.2:

1. **Al-Fe oxalate + low BD**: (Al_ox + 0.5*Fe_ox) >= `min_alfe` (default 2.0%) AND bulk_density <= `max_bd` (default 0.9 g/cm^3) on the same layer.
2. **Phosphate retention**: phosphate_retention_pct >= `min_p_retention` (default 70%).

Either path qualifies. The volcanic-glass criterion is the separate `vitric_properties` diagnostic; Andosols key on (andic OR vitric) at the RSG-gate level (`andosol`).

Usage

```
andic_properties(
  pedon,
  min_alfe = 2,
  max_bd = 0.9,
  min_p_retention = 70,
  min_oc_proxy = 4,
  max_bd_proxy = 0.9
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_alfe`	Minimum (Al_ox + 0.5*Fe_ox) percent for the Al-Fe path (default 2.0).
`max_bd`	Maximum bulk density g/cm^3 for the Al-Fe path (default 0.9).
`min_p_retention`	Minimum phosphate retention % for the P path (default 70).
`min_oc_proxy`	Minimum SOC % for the v0.9.80 OC+BD proxy path (default 4.0). Only consulted when the proxy is enabled via `options(soilKey.andic_oc_bd_proxy = TRUE)`.
`max_bd_proxy`	Maximum bulk density g/cm^3 for the v0.9.80 OC+BD proxy path (default 0.9). Only consulted when the proxy is enabled.

Value

A `DiagnosticResult`.

v0.9.80 OC + BD proxy (opt-in)

Field-described volcanic-ash soils (e.g.\ AfSP, KSSL/NASIS, SOTER) routinely lack oxalate Al/Fe and phosphate retention measurements, so the canonical paths return NA and Andosols cascade to other RSGs. The genetic signature is still detectable from coarser data: very high SOC (>= 4-5%) plus low bulk density (<= 0.9 g/cm^3) typical of allophanic / Al-humus complexation.

With options(soilKey.andic_oc_bd_proxy = TRUE) the function adds a third path that fires when both canonical paths fail and the surface horizon shows oc_pct >= min_oc_proxy AND bulk_density_g_cm3 <= max_bd_proxy (or OC alone >= 5% when BD is missing). Default is FALSE (canonical behaviour preserved).

v0.9.85 proxy contiguous-layer extension (opt-in)

When options(soilKey.andic_oc_bd_proxy_extend = TRUE) (only meaningful with soilKey.andic_oc_bd_proxy = TRUE), iteratively extend the proxy layers to include contiguous deeper layers whose oc_pct >= min_oc_proxy / 2 AND whose bulk_density_g_cm3 is missing OR <= max_bd_proxy + 0.15. The extension stops at the first horizon failing either constraint, so a ferralic / argic subsoil cannot accidentally inflate the andic thickness. Default is FALSE – canonical proxy behaviour preserved.

References

IUSS Working Group WRB (2022), Chapter 3, Andic properties.

---

andic_soil_properties_usda   *Andic soil properties (USDA, KST 13ed Ch 3, p 32)*

Description

Soil materials with one or both of the following:

- bulk_density <= 0.90 g/cm3 AND Al + 0.5*Fe (oxalate) >= 2.0% AND phosphate_retention >= 85%; OR
- Al + 0.5*Fe (oxalate) >= 0.4% AND phosphate_retention >= 25% AND volcanic_glass_pct varying with the texture-class proxy (deferred – requires fine-earth fraction analysis).

Usage

```
andic_soil_properties_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation (v0.8.6): primary "humic-andic" branch (bd <= 0.9 + Al+0.5Fe >= 2 + Pret >= 85). The vitric-andic branch (lower Al+Fe but high glass content) is partially captured.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, p 32.

`andic_subgroup_usda` *Andic Subgroup helper (USDA, KST 13ed)*

Description

Pass when, throughout one or more horizons with total thickness >= 18 cm within 75 cm of the surface:

- bulk_density_g_cm3 <= 1.0 (at 33 kPa); AND
- Al + 0.5 * Fe (oxalate-extractable) > 1.0 percent.

KST 13ed, p 117 (Andisols core, applies to subgroup criteria too).

Usage

```
andic_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

A `DiagnosticResult`.

`andisol_qualifying_usda` *Andisol Order qualifier (USDA, KST 13ed Ch 3, p 7)*

Description

Andisols have andic soil properties in 60%+ of the thickness between the surface and either:

- a depth of 60 cm; or
- a densic, lithic, or paralithic contact, a duripan, or a petrocalcic horizon (whichever is shallower).

v0.8.6 implementation: pass when total thickness of layers with andic_soil_properties is >= 0.6 * (depth from surface to 60 cm).

Usage

```
andisol_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

References

Soil Survey Staff (2022), KST 13ed, Ch. 6, p 117.

---

andisol_usda — *Andisols (USDA Cap 6): andic soil properties >= 60% of thickness.*

Description

Andisols (USDA Cap 6): andic soil properties >= 60% of thickness.

Usage

```
andisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

andosol — *Andosol RSG gate (WRB 2022 Ch 4, p 104)*

Description

WRB-canonical: layer(s) with *andic* OR *vitric* properties, combined thickness \>= 30 cm within 100 cm starting \<= 25 cm; OR \>= 60% of the entire soil thickness when a limiting layer starts 25-50 cm. Plus: no argic, ferralic, petroplinthic, pisoplinthic, plinthic or spodic horizon \<= 100 cm (unless buried below 50 cm).

Usage

```
andosol(pedon, min_thickness = 30, max_top_cm = 25, buried_below_cm = 50)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
max_top_cm	Numeric threshold or option (see Details).
buried_below_cm	Numeric: layers of the exclusion diagnostics whose top_cm \>= this depth are treated as buried and do NOT exclude the Andosol (default 50, per WRB 2022 Ch 4 p 104).

Details

v0.3.4 enforces (1) andic OR vitric AND (2) combined thickness \>= 30 cm starting in the upper 25 cm AND (3) the negative-list exclusions on argic / ferralic / plinthic / spodic.

v0.9.85 buried-exclusion fix

WRB 2022 Ch 4 p 104 specifies the Andosol exclusion list (argic / ferralic / petroplinthic / pisoplinthic / plinthic / spodic) as "<= 100 cm *unless buried below 50 cm*". The earlier implementation excluded an Andosol whenever any of those diagnostics passed anywhere in the profile, including on layers starting deeper than 50 cm – which mis-fires on AfSP Andosol references like `CM W3_0047`, where an argic layer at 56-72 cm wrongly excluded the andic surface stack. v0.9.85 restricts the exclusion check to layers starting <= 50 cm: a buried argic / ferralic / plinthic / spodic at deeper levels no longer disqualifies the surface andic stack from Andosol.

`anhydrous_conditions_usda` *Anhydrous conditions (USDA Soil Taxonomy, 13th edition)*

Description

"Anhydrous conditions refer to the moisture condition of soils in very cold deserts and other areas with permafrost (often dry permafrost). These soils typically have low precipitation (usually less than 50 mm water equivalent per year) and a moisture content of less than 3 percent by weight." – KST 13ed, Ch 3, p 33.

Usage

```
anhydrous_conditions_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Required characteristics:

- Mean annual soil temperature <= 0 C; AND
- Layer 10-70 cm with soil temperature < 5 C throughout the year; AND
- No ice-impregnated permafrost in that layer; AND
- One of:
  - Dry (>= 1500 kPa) in 1/2+ of soil for 1/2+ of time above 0 C; OR
  - Rupture-resistance class loose to slightly hard throughout when temp <= 0 C (except where pedogenically cemented).

Implementation (v0.8.x): Uses `permafrost_temp_C` from schema to flag layers below freezing; checks rupture_resistance for "loose" / "soft" / "slightly hard" in the 10-70 cm layer. Precipitation criterion is deferred to v0.9 (climatic data).

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, p 33.

`anionic_subgroup_usda` *Anionic Subgroup helper (Oxisols)*

Description

Pass when delta pH (KCl - water) is 0 or net positive in a 18+ cm layer within 125 cm. Indicates exchange complex dominated by positive-charge minerals (Fe/Al oxides).

Usage

```
anionic_subgroup_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`annotate_wrb_from_usda` *Annotate KSSL/NASIS pedons with a derived WRB Reference Soil Group*

Description

Applies `usda_to_wrb_rsg` to each pedon's USDA classification (preserved as `site$reference_usda` + `site$reference_usda_suborder` by `load_kssl_pedons_gpkg`) and writes the result to `site$reference_wrb_from_usda` – a "best-guess" expected WRB label for benchmark comparison.

Usage

```
annotate_wrb_from_usda(pedons)
```

Arguments

`pedons`	List of `PedonRecord` objects.

Details

Pedons that already have `site$reference_wrb` populated (e.g.\ from external sources) are left untouched.

Value

The same list, with `site$reference_wrb_from_usda` populated where USDA classification is present.

`anthraquic` *Anthraquic horizon (WRB 2022): puddled-rice / paddy plough layer. v0.3.3 detects via designation pattern* `Apl|Ap|Hh`.

Description

Anthraquic horizon (WRB 2022): puddled-rice / paddy plough layer. v0.3.3 detects via designation pattern `Apl|Ap|Hh`.

Usage

```
anthraquic(pedon, min_thickness = 20, max_top_cm = 50)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).

`anthric_horizons` *Anthric horizons (WRB 2022)*

Description

Tests for any of five anthropogenic surface horizons recognised by WRB 2022 (hortic, irragric, plaggic, pretic, terric). Diagnostic of Anthrosols. Two alternative paths qualify:

1. **Designation**: any layer's designation contains one of `hortic|irragric|plaggic|pretic|terric`.
2. **Property-based**: a surface layer (top_cm <= 5) at least `min_thickness_cm` cm thick (default 20) with elevated dark colour (Munsell value moist <= `max_munsell_value`, default 4) AND elevated plant-available P (`p_mehlich3_mg_kg` >= `min_p_mg_kg`, default 50).

Either path qualifies.

Usage

```
anthric_horizons(
  pedon,
  min_thickness_cm = 20,
  min_p_mg_kg = 50,
  max_munsell_value = 4
)
```

Arguments

`pedon` A `PedonRecord`.

`min_thickness_cm`
Minimum thickness for the property-based path (default 20).

`min_p_mg_kg` Minimum plant-available P (Mehlich 3, mg/kg) for the property-based path (default 50).

`max_munsell_value`
Maximum Munsell value moist for the property-based path (default 4).

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Anthrosols.

`aqualf_qualifying_usda` *Aqualf Suborder qualifier (aquic conditions in argillic Alfisol).*

Description

Aqualf Suborder qualifier (aquic conditions in argillic Alfisol).

Usage

```
aqualf_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`aquandic_subgroup_usda` *Aquandic Subgroup helper (Spodosols / others) Aquic + Andic.*

Description

Aquandic Subgroup helper (Spodosols / others) Aquic + Andic.

Usage

```
aquandic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`aquand_qualifying_usda` *Aquands Suborder qualifier (Cap 6, p 117) Pass when histic OR aquic conditions in 40-50 cm with redox features. Simplified: histic OR aquic_conditions(max_top=50).*

Description

Aquands Suborder qualifier (Cap 6, p 117) Pass when histic OR aquic conditions in 40-50 cm with redox features. Simplified: histic OR aquic_conditions(max_top=50).

Usage

```
aquand_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`aquent_qualifying_usda` *Aquent Suborder qualifier (Entisol with aquic conditions <50 cm).*

Description

Aquent Suborder qualifier (Entisol with aquic conditions <50 cm).

Usage

```
aquent_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`aquept_qualifying_usda` *Aquept Suborder qualifier*

Description

Aquept Suborder qualifier

Usage

```
aquept_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`aquert_qualifying_usda` *Aquerts qualifier (Vertisols with aquic conditions) Pass when aquic_conditions within 50 cm.*

Description

Aquerts qualifier (Vertisols with aquic conditions) Pass when aquic_conditions within 50 cm.

Usage

```
aquert_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

aquic_conditions_usda *Aquic conditions (USDA Soil Taxonomy, 13th edition)*

Description

"Soils with aquic conditions are those that currently undergo continuous or periodic saturation and reduction. The presence of these conditions is indicated by redoximorphic features, except in Histosols and Histels." – KST 13ed, Ch 3, p 41.

Usage

```
aquic_conditions_usda(
  pedon,
  max_top_cm = 100,
  min_redox_pct = 5,
  max_chroma = 2
)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Maximum depth at which saturation must occur (default 100 – typical for Suborder keys; 200 for some).
`min_redox_pct`	Threshold for redoximorphic features (default 5 percent).
`max_chroma`	Maximum chroma indicating reduction (default 2).

Details

Three types of saturation are defined:

- **Endosaturation**: saturated in all layers from the upper boundary of saturation to >=200 cm.
- **Episaturation**: saturated in one or more layers within 200 cm with unsaturated layer(s) below.
- **Anthric saturation**: cultivated/flood-irrigated.

Implementation (v0.8.x):

- Saturation is inferred from the presence of redoximorphic features (`redoximorphic_features_pct >= 5`) and/or a glei horizon (designation containing 'g').
- Reduction is inferred when chroma <= 2 in the matrix.
- Artificial drainage is treated as positive aquic when `site$artificially_drained == TRUE` (deferred – not in current schema).

Value

A `DiagnosticResult` with `evidence$saturation_type` = "endo" / "epi" / NA.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, pp 41-44.

`aquic_subgroup_usda` *Aquic Subgroup helper (within 100 cm of mineral soil surface)*

Description

Aquic Subgroup helper (within 100 cm of mineral soil surface)

Usage

```
aquic_subgroup_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`aquoll_qualifying_usda` *Aquolls qualifier (aquic conditions in mollic).*

Description

Aquolls qualifier (aquic conditions in mollic).

Usage

```
aquoll_qualifying_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

aquult_qualifying_usda

Aquult Suborder qualifier Pass when aquic_conditions within 50 cm.

Description

Aquult Suborder qualifier Pass when aquic_conditions within 50 cm.

Usage

```
aquult_qualifying_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

arenic_subgroup_usda

Arenic / Grossarenic Subgroup helper (Spodosols)

Description

Pass when texture class (fine-earth fraction) is sandy throughout from the surface to the top of the spodic horizon AND the spodic top depth falls in `[min_spodic_top, max_spodic_top]`.

Usage

```
arenic_subgroup_usda(pedon, min_spodic_top = 75, max_spodic_top = 125)
```

Arguments

`pedon`	A `PedonRecord`.
`min_spodic_top`	Default 75.
`max_spodic_top`	Default 125.

Details

Standard cuts: - "Arenic": 75-125 cm - "Grossarenic": 125+ cm (use min_spodic_top=125, max=Inf)

Value

A `DiagnosticResult`.

`arenic_texture` *Arenic texture (WRB 2022)*

Description

Tests whether the upper 100 cm is uniformly coarser than sandy loam (i.e., `silt + 2 * clay < 30` in every layer). Diagnostic of Arenosols.

Usage

```
arenic_texture(pedon, max_top_cm = 100, engine = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Maximum top depth (cm) of layers to be tested (default 100, per WRB 2022).
`engine`	One of `"soilkey"` (default; strict WRB sand threshold via `test_coarse_texture_throughout`) or `"aqp"` (LUCAS-friendly fallback: passes when sand >= 70\ reads `getOption("soilKey.diagnostic_`

Details

Sub-test: `test_coarse_texture_throughout`.

v0.3 limitations: WRB 2022 Arenosol also requires that no other diagnostic horizon (argic, ferralic, etc.) is present, but those exclusions happen at the key level via canonical RSG order.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Arenosols.

`argic` *Argic horizon (WRB 2022)*

Description

Tests whether any horizon meets the argic horizon criteria per Chapter 3 of the WRB 2022 (4th edition). Argic is a subsurface horizon with distinctly higher clay content than the overlying horizon, qualified by three depth-conditional clay-increase rules; it must also have texture of sandy loam or finer, satisfy a minimum thickness, and not exhibit albeluvic glossic features (which would direct the profile to the Retisol path).

Usage

```
argic(
  pedon,
  min_thickness = 7.5,
  system = c("wrb2022", "usda"),
  engine = NULL,
  require_t = NULL
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness in cm (default 7.5).
`system`	One of `"wrb2022"` (default) or `"usda"`. Selects the clay-increase threshold set: WRB uses 6/1.4/20 pp/ratio/pp; KST 13ed uses 3/1.2/8 (looser). See `test_clay_increase_argic` for the table.
`engine`	v0.9.63+. One of `"soilkey"` (the hand-coded path, default for back-compat) or `"aqp"` (canonical NRCS dispatch via `aqp::getArgillicBounds`). When `NULL` (the new default) the function reads `getOption("soilKey.diagnostic_engine", "soilkey")` so a global `options(soilKey.diagnostic_engine = "aqp")` flips every `argic()` call without modifying call sites. See `argic_aqp`.
`require_t`	v0.9.63+. Forwarded to `aqp::getArgillicBounds` when `engine = "aqp"`: `TRUE` requires a "t" suffix in the horizon designation (the strict KST 13ed text); `FALSE` accepts argic by clay-increase alone (more permissive on data-sparse profiles). `NULL` (default) auto-picks: `TRUE` for `system = "usda"`, `FALSE` for `system = "wrb2022"`. Ignored when `engine = "soilkey"`.

Details

Sub-tests called (each a list with `passed`, `layers`, `missing`, `details`, `notes`):

- `test_clay_increase_argic` – the three-pronged WRB 2022 clay-increase rule.
- `test_minimum_thickness` – thickness >= 7.5 cm (configurable via `min_thickness`).
- `test_texture_argic` – texture of sandy loam or finer (`silt + 2 * clay >= 30`).
- `test_not_albeluvic` – excludes profiles with glossic tongues (Retisol path).

v0.1 limitations: clay-increase distance (<= 30 cm vertical, or <= 15 cm with abrupt textural change) is not yet enforced; that is scheduled for v0.2 and depends on horizon boundary descriptions.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022). *World Reference Base for Soil Resources*, 4th edition. International Union of Soil Sciences, Vienna. Chapter 3 – Argic horizon.

argic_aqp *Argic / argillic horizon via aqp::getArgillicBounds()*

Description

Wraps `aqp::getArgillicBounds()` (Beaudette et al.) in soilKey's `DiagnosticResult` contract. The aqp implementation is the canonical NRCS R port and uses the tiered USDA-NRCS clay-increase thresholds:

- Eluvial clay < 15\
- Eluvial clay 15-40\
- Eluvial clay \>= 40\

(vs. soilKey's hand-coded `argic` which uses the WRB 6/1.4/20 thresholds). For BDsolos / FEBR / KSSL profiles the aqp rule is closer to KST 13ed and BDsolos field practice.

Usage

```
argic_aqp(pedon, require_t = FALSE, ...)
```

Arguments

`pedon`	A `PedonRecord`.
`require_t`	Whether to require an explicit "t" suffix in the horizon designation (default `FALSE` for BDsolos / FEBR; `TRUE` matches the strict KST 13ed text).
`...`	Reserved for future arguments.

Details

By default aqp requires a "t" suffix in the horizon designation (`require_t = TRUE`); we expose this so callers can be permissive on datasets where designation is missing or non-conforming (BDsolos exports often drop the "t").

Value

A `DiagnosticResult` with `name = "argic_aqp"`. `$layers` are the row indices of horizons in the argillic / argic depth interval. `$evidence` carries the raw aqp `c(ubound, lbound)` bounds for traceability.

See Also

`argic` (soilKey hand-coded; WRB 6/1.4/20), `aqp::getArgillicBounds`.

argic_aridisol_usda *Argic Aridisol helper – argillic-or-kandic in Argids/Cryids/etc.*

Description

Argic Aridisol helper – argillic-or-kandic in Argids/Cryids/etc.

Usage

```
argic_aridisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

argic_mollisol_usda *Argic Mollisol Suborder helper – delegates argillic_within_usda.*

Description

Argic Mollisol Suborder helper – delegates argillic_within_usda.

Usage

```
argic_mollisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

argic_subgroup_usda *Argic Subgroup helper (Endoaquods/Fragiaquods): argillic or kandic. Synonym of ultic at this level. Re-exported for naming clarity.*

Description

Argic Subgroup helper (Endoaquods/Fragiaquods): argillic or kandic. Synonym of ultic at this level. Re-exported for naming clarity.

Usage

```
argic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

argic_with_strong_clay_films

Test whether a pedon's argic horizon has strong clay films

Description

Wraps `argic()` and inspects the `clay_films_amount` field at the argic-passing layers. Returns a structured result that `B_latossolico()` uses to decide whether the SiBCS Cap 18 strong-films exclusion fires.

Usage

```
argic_with_strong_clay_films(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

A list with:

- `passed` – logical, `TRUE` only when argic passes AND at least one argic-passing layer has a strong (*comum* / *abundante*) film qualifier.
- `layers` – integer vector of argic-passing layer indices (empty when `passed` is `FALSE`).
- `argic` – the underlying `DiagnosticResult` from `argic()`.
- `films` – character vector of the `clay_films_amount` values at the argic-passing layers.

argillic_clay_films_test

Test for clay-illuviation evidence (KST 13ed Ch 3 p 4)

Description

KST 13ed argillic horizon requires "evidence of illuvial accumulation of clay" alongside the clay-increase rule. Acceptable evidence:

- oriented clays bridging sand grains in >= 1% of the horizon;
- clay films lining pores or coating ped faces;
- lamellae more than 5 mm thick.

Usage

```
argillic_clay_films_test(pedon)
```

Arguments

pedon A `PedonRecord`.

Details

This test reads three complementary slots, in order of evidence strength:

1. `pedon$site$nasis_diagnostic_features` – the NASIS `pediagfeatures.featkind` vector. The surveyor's explicit "Argillic horizon" entry directly confirms clay-illuviation evidence (~13 500 entries in the 2021 NASIS snapshot). Strongest evidence.
2. `pedon$horizons$clay_films_amount` – per-horizon clay-film abundance derived from NASIS `phpvsf`. Values: `"few"`, `"common"`, `"many"`, `"continuous"`. Direct measurement.
3. `pedon$horizons$designation` containing a 't' master suffix (e.g. `Bt`, `Btk`, `Btx`, `Bt1`, `2Bt`). v0.9.28: the pedologist who wrote that designation explicitly identified the horizon as clay-illuvial – per KST 13ed Ch 18, the 't' suffix means "accumulation of silicate clay" – so it counts as positive evidence even when NASIS records are absent. This unlocks the KST 13ed argillic thresholds for the ~47 pediagfeatures and phpvsf records.

Any of the three sources counts as positive evidence (logical OR). `passed = NA` when none is populated AND no horizon designation field is present at all (lab-only loaders without horizon descriptions). `passed = FALSE` when designations exist but none has a 't' suffix and NASIS slots are empty.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), Keys to Soil Taxonomy 13th ed., Ch. 3, argillic horizon (clay-illuviation criteria, p. 4); Ch. 18, master horizon symbols (`t`: silicate-clay accumulation, p. 332).

`argillic_or_kandic_usda` *Argillic-or-Kandic helper (USDA, used in Spodosols Subgroups)*

Description

Pass when EITHER an argillic OR a kandic horizon is present within `max_top_cm`.

Usage

```
argillic_or_kandic_usda(pedon, max_top_cm = 200, min_bs = NULL)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Default 200.
min_bs	Optional minimum BS for "Alfic" subgroups.

Value

A DiagnosticResult.

`argillic_usda` *Argillic horizon (USDA Soil Taxonomy)*

Description

v0.2 scaffold delegating to WRB `argic`. The two diagnostics' clay-increase rules are essentially the same; USDA argillic additionally requires evidence of clay illuviation (clay films / clay bridges) on at least 1% of the surface area, which v0.8 will enforce against the `clay_films_amount` column.

Usage

```
argillic_usda(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Passed to argic.

Value

A DiagnosticResult.

References

Soil Survey Staff (2014), Keys to Soil Taxonomy, Ch. 3 – argillic horizon.

argillic_within_usda *Argillic horizon helper (USDA, KST 13ed Ch 3)*

Description

Wrapper around argillic_usda that simply re-exports the DiagnosticResult with a max-depth check (default 100 cm for Argiorthels Subgroup keys).

Usage

```
argillic_within_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Default 100 cm.

Value

A `DiagnosticResult`.

argissolo *Argissolos (SiBCS Cap 4, p 114; conceito Cap 3, p 86-88)*

Description

Horizonte B textural – catch-all final na chave SiBCS apos Luvissolos / Nitossolos terem sido excluidos. v0.7 enforce: B textural + (argila ativ baixa OR ativ alta + V baixa OR carater alumínico).

Usage

```
argissolo(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`argissolo_acinzentado` *Argissolos Acinzentados (SiBCS Cap 5)*

Description

Matiz \>= 7.5YR, valor \>= 5, croma \< 4 (cores mais cinzentas / palidas), na maior parte do B (inclusive BA).

Usage

```
argissolo_acinzentado(pedon)
```

Arguments

pedon	A `PedonRecord`.

`argissolo_amarelo` *Argissolos Amarelos (SiBCS Cap 5)*

Description

Matiz \>= 7.5YR (mais amarelo) na maior parte do B, sem ser Acinzentado (croma \>= 4).

Usage

```
argissolo_amarelo(pedon)
```

Arguments

pedon	A `PedonRecord`.

`argissolo_bruno_acinzentado` *Argissolos Bruno-Acinzentados (SiBCS Cap 5)*

Description

Argissolos com horizonte B textural, com matiz \>= 5YR e cor escura (valor \<= 4 + croma \<= 4 umidos) na maior parte do B (inclusive BA).

Usage

```
argissolo_bruno_acinzentado(pedon)
```

Arguments

pedon	A `PedonRecord`.

`argissolo_vermelho` *Argissolos Vermelhos (SiBCS Cap 5)*

Description

Matiz \<= 2.5YR (mais vermelho) na maior parte do B.

Usage

```
argissolo_vermelho(pedon)
```

Arguments

pedon	A PedonRecord.

`argissolo_vermelho_amarelo` *Argissolos Vermelho-Amarelos (catch-all dos Argissolos)*

Description

Argissolos Vermelho-Amarelos (catch-all dos Argissolos)

Usage

```
argissolo_vermelho_amarelo(pedon)
```

Arguments

pedon	A PedonRecord.

`aridisol_qualifying_usda` *Aridisol Order qualifier (USDA, KST 13ed, Ch 2) Pass when the soil has aridic SMR AND any one of: argillic, natric, kandic, calcic, petrocalcic, gypsic, petrogypsic, salic, duripan, cambic, sulfuric horizon. Also requires no other prior order match.*

Description

Aridisol Order qualifier (USDA, KST 13ed, Ch 2) Pass when the soil has aridic SMR AND any one of: argillic, natric, kandic, calcic, petrocalcic, gypsic, petrogypsic, salic, duripan, cambic, sulfuric horizon. Also requires no other prior order match.

Usage

```
aridisol_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

aridisol_usda — *Aridisols (USDA Cap 7): aridic moisture regime + ochric/anthropic + subsurface diagnostic. v0.8 simplification: detected via aridity proxies (low EC OR salic OR caracter combinations) + non-mollic surface + low OC (no organic accumulation).*

Description

Aridisols (USDA Cap 7): aridic moisture regime + ochric/anthropic + subsurface diagnostic. v0.8 simplification: detected via aridity proxies (low EC OR salic OR caracter combinations) + non-mollic surface + low OC (no organic accumulation).

Usage

```
aridisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

artefacts — *Artefacts (WRB 2022 Ch 3.3.2)*

Description

Per the canonical definition: human-made / human-altered / human- excavated material. v0.3.3 returns the layers where `artefacts_pct` >= 1.

Usage

```
artefacts(pedon, min_pct = 1)
```

Arguments

pedon	A PedonRecord.
min_pct	Numeric threshold or option (see Details).

as_aqp *Convert one or more PedonRecord objects to an aqp SoilProfileCollection*

Description

Builds a `aqp::SoilProfileCollection` from one `PedonRecord` or a list of them. Standard soilKey columns (`top_cm`, `bottom_cm`, `designation`, `clay_pct`, `sand_pct`, `silt_pct`) are renamed to aqp's canonical convention (`top`, `bottom`, `name`, `clay`, `sand`, `silt`). All other columns are passed through unchanged. Site-level slots (`lat`, `lon`, `country`, `parent_material`, `reference_*`, `nasis_diagnostic_features`, etc.) are attached to the SPC's site table.

Usage

```
as_aqp(x)
```

Arguments

x	A `PedonRecord` or a list of them.

Details

Requires the `aqp` package, listed in Suggests; the function raises a clear error if aqp is not installed.

Value

A `aqp::SoilProfileCollection`.

See Also

`from_aqp`, the inverse conversion.

Examples

```
if (requireNamespace("aqp", quietly = TRUE)) {
  pedons <- list(make_ferralsol_canonical(), make_luvisol_canonical())
  spc <- as_aqp(pedons)
  length(spc)         # 2 profiles
  aqp::horizons(spc)  # one row per horizon, aqp-named columns
}
```

`atividade_argila_alta` *Atividade da fracao argila (SiBCS Cap 1, p 30)*

Description

Calcula a atividade da fracao argila Ta = CEC * 1000 / argila (em cmolc/kg de argila, sem correcao para carbono) por horizonte e classifica como **alta (Ta)** se >= 27 cmolc/kg argila ou **baixa (Tb)** se < 27. Nao se aplica a texturas areia / areia franca.

Usage

```
atividade_argila_alta(pedon, min_ta = 27)
```

Arguments

`pedon`	A `PedonRecord`.
`min_ta`	Numeric threshold or option (see Details).

Details

Para distincao de classes pelo SiBCS, considera-se a atividade no horizonte B (incl. BA, exc. BC) ou no horizonte C (incl. CA), quando nao existe B.

Value

Um `DiagnosticResult`; `passed` = `TRUE` sse pelo menos um horizonte B ou C tem Ta. `layers` = horizontes com atividade alta (Ta).

References

Embrapa (2018), SiBCS 5a ed., Cap 1, "Atividade da fracao argila", p. 30.

`attach_lucas_spectra` *Attach LUCAS 2018 Vis-NIR spectra to a list of PedonRecord objects*

Description

Joins the LUCAS Soil 2018 Spectral Library (separate ESDAC release, ~83 GB) onto the pedons returned by `load_lucas_soil_2018`, by matching the LUCAS `POINT_ID` of the spectra against `pedon$site$id`. Each matched pedon gets `$spectra$vnir` populated as a numeric matrix (rows = horizons, cols = wavelengths).

Usage

```
attach_lucas_spectra(
  pedons,
  spectra,
  point_id_col = "POINT_ID",
  verbose = TRUE
)
```

Arguments

pedons	List of PedonRecord objects.
spectra	A wide or long data.frame as described above.
point_id_col	Name of the LUCAS point-id column in spectra. Default "POINT_ID".
verbose	If TRUE (default), reports the join hit rate.

Details

Two input shapes are accepted:

- A wide data.frame keyed by an integer POINT_ID column with one column per wavelength (column names parseable as numeric nm). One row per LUCAS point.
- A long data.frame with columns POINT_ID, wavelength_nm, reflectance.

Spectra are attached only to the topsoil horizon (row 1); the subsoil horizon (if any) is left without spectra. After this call, benchmark_lucas_2018(..., fill_topsoil_from = "spectra", ossl_models = ...) feeds the spectra through predict_from_spectra (v0.9.46) to fill any chemistry / texture gap not already populated by SoilGrids.

Value

The list of pedons (mutated in place; returned invisibly).

See Also

predict_from_spectra, predict_munsell_from_spectra, load_lucas_soil_2018.

---

audit_argic_strong_films

Audit the strong-clay-films exclusion across a list of pedons

---

Description

Applies argic_with_strong_clay_films() to every pedon in pedons and returns a per-pedon table summarising how the v0.9.61 B_latossolico() latossolic-vs-argic rule resolves on the benchmark sample.

Usage

```
audit_argic_strong_films(pedons, reference_filter = NULL)
```

Arguments

pedons List of `PedonRecord` objects.

reference_filter
: Optional regex applied to `p$site$reference_sibcs` to keep only pedons whose reference matches (case-sensitive, ICU). Default `NULL` keeps every pedon.

Details

Useful for empirical validation of the SiBCS Cap 18 precedence rule on field-described datasets such as BDsolos and Redape, where clay-film qualifiers are recorded in mixed Portuguese / English tokenisation. The audit is read-only and never invokes `classify_sibcs()`.

Value

A `data.frame` with columns `id`, `reference_sibcs`, `argic_passed`, `has_films_at_argic`, `strong_films_at_argic`, and `would_exclude_from_latossolo`.

Examples

```
csv_path <- "RJ.csv"
if (file.exists(csv_path)) {
  peds <- load_bdsolos_csv(csv_path)
  a <- audit_argic_strong_films(peds, reference_filter = "LATOSSOLO")
  table(a$would_exclude_from_latossolo)
}
```

---

auto_set_proj_env *Auto-detect PROJ_LIB and GDAL_DATA directories*

Description

Probes the common system locations for PROJ `proj.db` and GDAL data directories, on macOS Homebrew (Apple silicon and Intel), Linuxbrew, conda / mamba environments, and Debian / Ubuntu / Fedora apt or dnf installs. Sets the corresponding environment variables only when they are not already set, so a user-provided value always wins. Idempotent: safe to call repeatedly.

Usage

```
auto_set_proj_env(verbose = FALSE)
```

Arguments

verbose If `TRUE`, emits a `cli` message confirming what was detected.

Details

Called automatically from `.onLoad`; call manually after installing PROJ / GDAL via Homebrew if you want to refresh the env without restarting R.

Value

Invisibly, a named list with `PROJ_LIB` and `GDAL_DATA` (the values that were set, or `NA_character_` if a value was already present or no candidate was found).

`available_esdb_attributes` *List ESDB Raster Library attributes available at a given root*

Description

Walks ‘raster_root‘ and returns the folder names that contain a valid ‘<NAME>.tif‘ raster. Useful for discovery before calling `lookup_esdb`.

Usage

```
available_esdb_attributes(raster_root)
```

Arguments

`raster_root`	Path to the unpacked ESDB raster directory (typically ‘<some>/ESDB-Raster-Library-1k-GeoTIFF-...‘).

Value

A character vector of attribute names (sorted).

Examples

```
root <- file.path(tempdir(), "ESDB-Raster-Library-1k-GeoTIFF-20240507")
if (dir.exists(root)) {
  available_esdb_attributes(root)
}
```

batch_robustness *Batch robustness across many pedons*

Description

Runs classification_robustness on each pedon in a list and returns a tidy data.frame with one row per pedon. Useful for paper-grade claims like "85 to a 5

Usage

```
batch_robustness(pedons, ...)
```

Arguments

pedons	List of PedonRecord objects.
...	Passed to classification_robustness.

Value

A data.frame with columns id, baseline, robustness, n_flipped.

Examples

```
pedons <- list(make_ferralsol_canonical(),
                 make_luvisol_canonical(),
                 make_chernozem_canonical())
batch_robustness(pedons, system = "wrb2022", n = 50)
#>            id   baseline robustness n_flipped
#> 1 FR-canon-01 Ferralsols       0.96         2
#> 2 LV-canon-01   Luvisols       1.00         0
#> 3 CH-canon-01 Chernozems       0.94         3
```

benchmark_afsp *Benchmark soilKey WRB predictions against AfSP ground truth*

Description

Benchmark soilKey WRB predictions against AfSP ground truth

Usage

```
benchmark_afsp(pedons, verbose = TRUE)
```

Arguments

pedons	List of PedonRecord from load_afsp_pedons or load_afsp_sample.
verbose	Print progress.

Value

List with accuracy, n_compared, confusion, per_class_recall.

---

benchmark_bdsolos *Benchmark soilKey classifiers against BDsolos national reference labels*

Description

Runs classify_wrb2022, classify_sibcs, and classify_usda on each PedonRecord loaded from a BDsolos CSV via load_bdsolos_csv, then compares each predicted classification against the corresponding BDsolos reference label (reference_sibcs, reference_wrb, reference_st) and reports per-system accuracy, per-class recall, and a confusion matrix.

Usage

```
benchmark_bdsolos(
  pedons,
  systems = c("wrb2022", "sibcs", "usda"),
  sibcs_level = c("order", "subordem"),
  max_n = NULL,
  verbose = TRUE
)
```

Arguments

pedons	A list of PedonRecord objects, typically produced by load_bdsolos_csv.
systems	Character vector. Any subset of c("wrb2022","sibcs", "usda"). Default runs all three.
sibcs_level	One of "order" (default) or "subordem". Forwarded to normalise_febr_sibcs.
max_n	Optional integer; cap classification at the first max_n pedons. NULL (default) classifies every pedon.
verbose	If TRUE (default), emits cli progress messages.

Value

A list with elements:

- per_system – named list (one entry per requested system) of list(accuracy, n_compared, n_correct, n_errors, confusion, per_class) (or list(accuracy = NA_real_, message) when no reference labels were present).
- coverage – named list of list(n_with_ref, n_total, pct) per system.
- config – named list capturing n_pedons, systems, sibcs_level, soilKey_version, timestamp.

Reference label coverage

BDsolos densely populates reference_sibcs (~82 of the v0.9.59 audit) but sparsely populates reference_wrb and reference_st (UF-dependent; ~5 states). The function always reports the per-system label coverage ($coverage) so the caller can judge how representative each accuracy figure is.

Comparison level

SiBCS comparison is at level = "order" by default, which converts the BDsolos all-caps Portuguese label (e.g. "ARGISSOLO VERMELHO Tb EUTROFICO ...") to the soilKey plural Title Case form ("Argissolos") via normalise_febr_sibcs. Set sibcs_level = "subordem" to compare the first two SiBCS tokens (Ordem + Subordem).

WRB and USDA comparisons are at the Reference Soil Group / Order level: normalise_febr_wrb() strips qualifier parens and pluralises the bare RSG ("Xanthic Ferralsol" -> "Ferralsols"); normalise_febr_usda() maps the suffix of the last subgroup token to the USDA Order ("Typic Haplorthox" -> "Oxisols").

Errors and missing-label handling

Pedons without a reference label for a given system are silently excluded from THAT system's comparison (but still classified for the other two systems). If a system has zero pedons with a reference label, the corresponding $per_system entry has accuracy = NA_real_ and message = "no_reference_labels". Classifier errors are caught per-pedon and recorded in n_errors; they do not abort the run.

See Also

load_bdsolos_csv, benchmark_lucas_2018, classify_all, normalise_febr_sibcs, normalise_febr_wrb, normalise_febr_usda.

Examples

```
# Requires a user-provided BDsolos CSV; guarded so the example
# no-ops on CRAN when the file is absent.
csv_path <- "RJ.csv"
if (file.exists(csv_path)) {
  peds <- load_bdsolos_csv(csv_path)
  bench <- benchmark_bdsolos(peds, systems = c("sibcs", "wrb2022", "usda"))
  bench$coverage      # how many pedons had each reference label
  bench$per_system$sibcs$accuracy
  bench$per_system$sibcs$confusion

  # Subordem level
  bench2 <- benchmark_bdsolos(peds, systems = "sibcs",
                              sibcs_level = "subordem")
}
```

benchmark_lucas_2018 *Run the LUCAS Soil 2018 / ESDB WRB benchmark*

Description

For each pedon in pedons, attaches the canonical Reference Soil Group at its coordinate via `lookup_esdb`, runs `classify_wrb2022` (or `classify_sibcs`), and tabulates predicted vs reference. Optionally fills missing texture from ISRIC SoilGrids 250m before classifying so that WRB diagnostic horizons that depend on clay (argic, ferralic, nitic) are reachable.

Usage

```
benchmark_lucas_2018(
  pedons,
  esdb_root,
  attribute = "WRBLV1",
  fill_texture_from = NULL,
  fill_topsoil_from = c("none", "soilgrids", "spectra"),
  fill_subsoil_from = c("none", "soilgrids"),
 fill_properties = c("clay", "sand", "silt", "phh2o", "soc", "cec", "bdod", "nitrogen",
    "cfvo"),
  ossl_models = NULL,
  classify_with = c("wrb2022", "sibcs"),
  max_n = NULL,
  soilgrids_lookup_fn = lookup_soilgrids,
  verbose = TRUE
)
```

Arguments

`pedons` List of `PedonRecord` objects, typically from `load_lucas_soil_2018`.

`esdb_root` Path to the unpacked ESDB raster directory (containing the `WRBLV1/` sub-folder).

`attribute` ESDB attribute to use as reference. Default `"WRBLV1"` (Reference Soil Group, 31 codes). Other sensible choices: `"FAO90LV1"` (legacy FAO 1990).

`fill_texture_from`
Deprecated alias for `fill_topsoil_from` (v0.9.49 signature). When `"soilgrids"`, treated as `fill_topsoil_from = "soilgrids"` with `fill_properties = c("clay", "sand", "silt")` and `fill_subsoil_from = "none"`.

`fill_topsoil_from`
One of `"none"` (default), `"soilgrids"` (fills topsoil 0-20 cm from SoilGrids 250m at 0-5 cm), or `"spectra"` (runs `predict_from_spectra` with the supplied `ossl_models`; pedons must have `$spectra$vnir` attached, e.g. via `attach_lucas_spectra`).

`fill_subsoil_from`
One of `"none"` (default) or `"soilgrids"` (synthesises a 30-60 cm B horizon from SoilGrids 250m). Unlocks WRB diagnostic horizons that depend on subsoil features (cambic, argic, mollic).

fill_properties
: Character vector of SoilGrids properties to fill when fill_topsoil_from = "soilgrids" or fill_subsoil_from = "soilgrids". Default uses all 9 properties: clay, sand, silt, phh2o, soc, cec, bdod, nitrogen, cfvo. Set to c("clay", "sand", "silt") to recover the v0.9.49 behaviour. cfvo is mapped to coarse_fragments_pct, which drives the Leptosols diagnostic (>= 90 within 25 cm).

ossl_models
: Required when fill_topsoil_from = "spectra". A list of soilKey_pls_model objects from train_pls_from_ossl (v0.9.46).

classify_with
: One of "wrb2022" (default) or "sibcs".

max_n
: Optional integer cap on the number of pedons benchmarked. Useful for quick development runs.

soilgrids_lookup_fn
: Internal: SoilGrids lookup function (defaults to lookup_soilgrids). Override for unit tests to inject a deterministic stub.

verbose
: If TRUE (default), prints progress.

Details

This closes Route B of the v0.9.27 EU-LUCAS roadmap end-to-end: v0.9.44 lookup_esdb provides the reference label; v0.9.49 (this) provides the loader and the comparison loop; v0.9.48 lookup_soilgrids fills texture; v0.9.46 predict_from_spectra and v0.9.47 predict_munsell_from_spectra can fill the chemistry / Munsell gaps when Vis-NIR is available.

Value

A list with elements:

predictions data.frame with one row per pedon: point_id, lon, lat, country, predicted, reference_code, reference_name, agree.

confusion Confusion table (predicted vs reference) over in-scope rows.

accuracy Overall fraction of correct classifications among in-scope rows.

per_rsg Per-RSG recall data.frame.

n_in_scope Number of pedons with both predicted and reference set.

n_total Total pedons benchmarked.

n_errors Number of pedons where the classifier errored out.

errors List of (i, id, error) tuples for classifier errors.

config Recap of arguments used.

See Also

load_lucas_soil_2018, lookup_esdb, lookup_soilgrids.

Examples

```
lucas_dir <- file.path(tempdir(), "LUCAS-SOIL-2018-v2")
esdb_dir  <- file.path(tempdir(), "ESDB-Raster-Library-1k-GeoTIFF-20240507")
if (dir.exists(lucas_dir) && dir.exists(esdb_dir)) {
  pedons <- load_lucas_soil_2018(lucas_dir, countries = "ES", max_n = 50)
  bench <- benchmark_lucas_2018(
    pedons,
    esdb_root = esdb_dir,
    fill_texture_from = "soilgrids")
  bench$accuracy
  bench$per_rsg
}
```

---

benchmark_performance   *Run the soilKey performance benchmark*

Description

Generates n synthetic pedons (5 horizons each, with the chemistry / morphology populated for typical Argissolo / Latossolo / Cambissolo cases), calls each classifier on each pedon, and reports per-call latency + total throughput.

Usage

```
benchmark_performance(
  n = 100L,
  systems = c("wrb2022", "sibcs", "usda"),
  include_familia = FALSE,
  seed = 42L,
  verbose = TRUE
)
```

Arguments

n	Integer. Number of synthetic pedons to generate. Default 100; pass 1000 or higher for batch-level measurements.
systems	Character vector. Which classifiers to time. Default `c("wrb2022", "sibcs", "usda")` (all three).
include_familia	Pass-through to `classify_sibcs` when `"sibcs"` is in `systems`. Default `FALSE`.
seed	Integer applied through `with_seed` so the synthetic pedon pool is reproducible *without* mutating the caller's global RNG state. Pass `NULL` to leave the RNG stream untouched. Default `42L` preserves the bit-for-bit-identical pool earlier soilKey releases produced (CRAN policy: never call `set.seed()` on the caller's RNG).
verbose	If `TRUE` (default), prints a per-system summary line.

Details

Designed to be a one-shot reproducible benchmark: the synthetic pedons use a fixed RNG seed so timings on the same machine are comparable across releases.

Value

A list with elements:

- `summary` data.frame: `system`, `n_pedons`, `total_seconds`, `mean_seconds`, `median_seconds`, `pedons_per_minute`.
- `per_pedon` data.frame with one row per (pedon, system) call: `i`, `system`, `seconds`, `status`.
- `config` list with `n`, `seed`, `soilKey_version`, `R_version`, `platform`.

Examples

```
bench <- benchmark_performance(n = 5)
bench$summary
```

`benchmark_redape` *Benchmark soilKey SiBCS predictions against the Redape gold standard*

Description

Runs `classify_sibcs` on each pedon and compares against the curator-validated reference label (Order / Suborder / Great Group / Subgroup). Returns per-level accuracy and the confusion matrix at the requested granularity.

Usage

```
benchmark_redape(
  pedons,
  level = c("order", "subordem", "gde_grupo", "subgrupo"),
  verbose = TRUE
)
```

Arguments

`pedons`	List of `PedonRecord` objects (typically from `load_redape_pedons`).
`level`	One of `"order"` (default), `"subordem"`, `"gde_grupo"`, or `"subgrupo"`.
`verbose`	Print progress (default `TRUE`).

Value

A list with `accuracy`, `n_compared`, `confusion`, `per_class_recall`, and the per-pedon `predictions` table. `predictions` now also includes columns `ref_norm` and `pred_norm` – the canonical comparison keys – for downstream auditing.

v0.9.81 level-aware comparison

Earlier versions accepted the `level` argument but always used `rsg_or_order` for the prediction and the order field for the reference, so all four levels reported identical accuracy. v0.9.81 reads the level-specific slots from `res$trace` (subordem, grande_grupo, subgrupo) and concatenates the matching reference fields, applying SiBCS-aware Portuguese pluralisation so the comparison key matches the predictor's plural Title Case form.

`benchmark_run_classification` *Run a benchmark across one of the loaded pedon lists*

Description

Classifies each pedon in `pedons` against the named system, compares against the published reference (e.g. `site$reference_wrb`), and returns a confusion matrix + top-1 / top-3 accuracy + bootstrap CI on top-1.

Usage

```
benchmark_run_classification(
  pedons,
  system = c("wrb2022", "sibcs", "usda"),
  level = c("order", "subgroup", "subordem", "great_group", "suborder"),
  boot_n = 1000L,
  seed = NULL
)
```

Arguments

`pedons` List of PedonRecord objects (output of one of the `load_*` functions).

`system` One of `"wrb2022"`, `"sibcs"`, `"usda"`.

`level` Granularity of the comparison:

- `"order"` (default) – the top-level RSG / Ordem / Order, compared against `cls$rsg_or_order`;
- `"subgroup"` – the full classified name (Subgroup in USDA, Subgrupo in SiBCS, RSG + qualifiers in WRB), compared against `cls$name` after case-insensitive token normalisation;
- `"subordem"` – SiBCS-only, the 2nd-level "Ordem + Subordem" (e.g. "Latossolos Vermelhos"). Comparison via the first two normalised tokens of the predicted name vs the reference;
- `"great_group"` (USDA, v0.9.24) – the LAST token of the subgroup name (e.g. `"typic hapludalfs"` -> `"hapludalfs"`). Isolates whether the Great Group machinery is correct independent of subgroup modifiers (Typic / Aquic / Vertic / Cumulic / Pachic / etc.). Reads `site$reference_usda_grtgroup`;

- "suborder" (USDA, v0.9.24) – maps the Great Group prediction to its canonical Suborder suffix ("hapludalfs" -> "udalfs") using the KST 13ed Ch 4 ~70-Suborder list. Reads site$reference_usda_suborder.

boot_n
: Bootstrap replicates for CI (default 1000).

seed
: Optional integer passed to with_seed to make the bootstrap reproducible without mutating the caller's global RNG state. When NULL (default), the bootstrap uses the current RNG stream untouched.

Value

A list with elements accuracy_top1, accuracy_ci, confusion, and per_pedon (one row per pedon with predicted vs reference).

---

benchmark_unified *Unified cross-dataset benchmark across SiBCS / WRB / USDA*

Description

Runs a system's soilKey classifier on every dataset that has reference labels for that system, then pools the results into a single nation-/world-wide accuracy estimate.

Usage

```
benchmark_unified(
  systems = c("all", "wrb2022", "sibcs", "usda"),
  datasets = c("all", "bdsolos", "febr", "kssl", "lucas_esdb"),
  paths = NULL,
  max_n_per_dataset = NULL,
  engine = c("soilkey", "aqp", "both"),
  harmonize = FALSE,
  verbose = TRUE
)
```

Arguments

systems
: Character vector. Any subset of c("wrb2022","sibcs", "usda"). Default "all" runs all three.

datasets
: Character vector. Any subset of c("bdsolos", "febr", "kssl", "lucas_esdb"). Default "all" pools every dataset that has reference labels for the requested systems. Datasets without reference labels for a system are silently excluded from that system's pooled result.

paths
: Named list of dataset paths. Element names should match those in datasets. If NULL (default), soilKey looks for canonical paths under "~/soil_data/".

max_n_per_dataset
: Optional integer to cap per-dataset sample size (useful for development / debugging). NULL (default) classifies every available pedon.

`engine`	Currently forwarded to Phase-1 aqp wiring. One of `"soilkey"` (default), `"aqp"`, `"both"`. When `"aqp"`, sets `options(soilKey.diagnostic_engine = "aqp")` for the duration of the benchmark, which routes `argic()` / `cambic()` through the canonical `aqp::getArgillicBounds` / `getCambicBounds`.
`harmonize`	If `TRUE` (default `FALSE`), applies `harmonize_to_gsm` to each dataset's pedons before classification, putting all chemistry/texture on the GSM depth grid (0-5 / 5-15 / 15-30 / 30-60 / 60-100 / 100-200 cm). Required for cross-dataset pooling integrity (Phase 2.3) but slow (~1-2 min for 1k pedons) and may degrade per-dataset accuracy slightly because the splined depths are approximations.
`verbose`	If `TRUE` (default), emits cli progress.

Value

A list with elements:

- `per_system` – per-system pooled `list(accuracy, n_compared, n_correct, confusion, per_class)`.
- `per_system_per_dataset` – per-(system, dataset) same shape, for breakdown.
- `coverage` – per-(system, dataset) sample sizes and label coverage.
- `config` – captures `systems`, `datasets`, `engine`, `soilKey_version`, `timestamp`.

Datasets and their reference labels

Dataset	Systems with reference labels
BDsolos	SiBCS (dense), WRB (sparse), USDA (sparse)
FEBR superconjunto	SiBCS, WRB, USDA (most rows have all 3)
KSSL+NASIS	USDA only (samp_taxsubgrp universal)
LUCAS + ESDB raster	WRB (via lookup_esdb on coords)

For each (system, dataset) pair, this function:

1. Loads pedons via the appropriate `load_*` helper.
2. Filters to pedons with a populated reference label for the requested system.
3. Normalises both reference and predicted labels via `normalise_febr_*()` / KSSL canonicalisation helpers.
4. Calls the system's classifier and records pred-vs-ref.

Then pools per-system results across datasets.

Engine selection (Phase 1 wiring)

For datasets with morphological data (BDsolos / FEBR), the diagnostics that pivot Argissolos / Latossolos / Cambissolos classification can be run with two engines:

- `engine = "soilkey"` (default) – the hand-coded WRB 6/1.4/20 thresholds.
- `engine = "aqp"` – aqp::getArgillicBounds / getCambicBounds (KST 13ed 3/1.2/8 thresholds).

On the v0.9.62 RJ benchmark (722 perfis), aqp was 14.8 pp stricter on argic and 40.6 pp more permissive on cambic; the SiBCS Argissolos / Latossolos / Cambissolos boundary is sensitive to both. engine is currently forwarded to a future v0.9.63 wired argic() / cambic(); for now, benchmark_unified() reports separately per engine when engine = "both".

See Also

benchmark_bdsolos, benchmark_lucas_2018, benchmark_run_classification, harmonize_to_gsm.

---

benchmark_wrb_vs_usda *Benchmark soilKey WRB predictions against a USDA-derived ground truth*

Description

Convenience wrapper: applies annotate_wrb_from_usda to attach derived WRB labels, runs classify_wrb2022 on each pedon, and returns top-1 accuracy + per-RSG recall.

Usage

```
benchmark_wrb_vs_usda(pedons, verbose = TRUE)
```

Arguments

pedons	List of PedonRecord objects with site$reference_usda populated (typically from load_kssl_pedons_gpkg).
verbose	Print progress.

Value

A list with accuracy, n_compared, confusion, per_class_recall.

B_espodico *Horizonte B espodico (SiBCS Cap 2, p 62-65; v0.7)*

Description

Subsuperficial com acumulo iluvial de Al + Fe + materia organica; espessura \>= 2.5 cm. Tipos: Bs, Bhs, Bh, ortstein. Reuso de spodic (WRB) que ja codifica criterios essencialmente identicos.

Usage

```
B_espodico(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Reserved for future arguments.

`B_incipiente` *Horizonte B incipiente (SiBCS Cap 2, p 59-61; v0.7)*

Description

Subsuperficial sob A/Ap/AB com alteracao fisica e quimica incipiente, NAO satisfazendo a B textural / latossolico / nitico / espodico / planico, com:

- espessura \>= 10 cm;
- textura francoarenosa ou mais fina;
- < 50% estrutura da rocha original;
- evidencias de pedogenese (cor mais viva OR remocao de carbonatos OR designation `Bw/Bi`);
- NAO satisfaz: argic, ferralic, espodic, planic, e nao tem duripa/petrocalcico/fragipa.

Usage

```
B_incipiente(pedon, min_thickness = 10)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).

`B_latossolico` *Horizonte B latossolico (SiBCS Cap 2, p 57-59; v0.7 strict)*

Description

Adicionalmente a `ferralic` (WRB), o B latossolico SiBCS exige:

- Espessura minima de 50 cm;
- Textura francoarenosa ou mais fina;
- Estrutura granular muito pequena/pequena ou em blocos subangulares fraco/moderado;
- < 5% volume mostrando estrutura da rocha original;
- Ki \<= 2.2 (geralmente \<= 2.0);
- Cerosidade no maximo pouca e fraca.

v0.7 enforce thickness, texture, e ausencia de estrutura primaria herdada via designation e clay; Ki/Kr quantitativos sao v0.8 (precisa de SiO2/Al2O3 lab-data nao no schema).

Usage

```
B_latossolico(
  pedon,
  min_thickness = 50,
  max_cec_per_clay = NULL,
  engine = NULL,
  ...
)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
max_cec_per_clay	Numeric threshold or option (see Details). Defaults to NULL (engine-aware): 17 in soilkey engine (the SiBCS-loose threshold, slightly more permissive than strict WRB ferralic 16) or 20 in aqp engine (v0.9.68 regional tolerance for Embrapa lab methodology offset).
engine	One of "soilkey" (default) or "aqp"; NULL reads getOption("soilKey.diagnostic_engine"). Forwarded to ferralic.
...	Reserved for future arguments.

B_nitico *Horizonte B nitico (SiBCS Cap 2, p 61-62; v0.7)*

Description

Subsuperficial nao hidromorfico, textura argilosa/muito argilosa (clay \>= 35% desde a superficie), com pequeno incremento de argila (B/A \<= 1.5), estrutura em blocos sub/angulares ou prismatica grau moderado/forte, cerosidade no minimo comum + moderada, espessura \>= 30 cm. Argila ativ baixa OR ativ alta + carater aluminico.

Usage

```
B_nitico(
  pedon,
  min_thickness = 30,
  min_clay_pct = 35,
  max_b_a_ratio = 1.5,
  min_cerosidade = c("common", "many", "abundant", "strong")
)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
min_clay_pct	Numeric threshold or option (see Details).
max_b_a_ratio	Numeric threshold or option (see Details).
min_cerosidade	Numeric threshold or option (see Details).

B_planico *Horizonte B planico (SiBCS Cap 2, p 65-66; v0.7)*

Description

Tipo especial de B textural com mudanca textural abrupta + permeabilidade lenta + cores neutras/escurecidas + cromas baixos.

Usage

```
B_planico(pedon)
```

Arguments

pedon	A PedonRecord.

B_textural *Horizonte B textural (SiBCS Cap 2, p 54-57; v0.7 strict)*

Description

Horizonte mineral subsuperficial com incremento de argila + cerosidade OR aumento gradativo, satisfazendo criterios de espessura e relacao textural B/A. v0.7 enforce as alternativas (a)-(j) do SiBCS por delegacao parcial ao WRB argic (criterios de clay-increase essencialmente identicos) acrescidos de:

- espessura \>= 7.5 cm OR \>= 10% da soma das espessuras dos sobrejacentes; e
- textura \>= francoarenosa.

Refinamentos pendentes para v0.8: cerosidade obrigatoria sob certas estruturas (criterio i.1 / i.2 / i.3); lamelas \>= 15 cm combinadas.

Usage

```
B_textural(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Reserved for future arguments.

calcaric_material — *Calcaric material (WRB 2022 Ch 3.3.3): \>= 2% CaCO3 throughout the fine earth, primary carbonates from the parent material.*

Description

Calcaric material (WRB 2022 Ch 3.3.3): \>= 2% CaCO3 throughout the fine earth, primary carbonates from the parent material.

Usage

```
calcaric_material(pedon, min_caco3_pct = 2)
```

Arguments

pedon	A PedonRecord.
min_caco3_pct	Numeric threshold or option (see Details).

calcic — *Calcic horizon (WRB 2022)*

Description

Tests whether any horizon meets the calcic horizon criteria. The calcic horizon is a horizon of secondary carbonate accumulation, diagnostic for Calcisols and qualifying many other RSGs.

Usage

```
calcic(pedon, min_thickness = 15, min_caco3_pct = 15)
```

Arguments

pedon	A PedonRecord.
min_thickness	Minimum thickness in cm (default 15).
min_caco3_pct	Minimum CaCO3 percent in fine earth (default 15).

Details

Sub-tests called:

- test_caco3_concentration – CaCO3 >= 15%.
- test_minimum_thickness – thickness >= 15 cm.

v0.2 limitations: the WRB criterion of "5% absolute or relative more CaCO3 than the underlying horizon" is not enforced; this captures true calcic horizons but may also mark uniformly carbonate-rich substrates that are not pedologically calcic. Cementation (petrocalcic) is not yet detected. Both refinements are scheduled for v0.3.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022). *World Reference Base for Soil Resources*, 4th edition. International Union of Soil Sciences, Vienna. Chapter 3 – Calcic horizon.

`calcic_horizon_usda` *Calcic horizon (USDA, delegates to WRB calcic).*

Description

Calcic horizon (USDA, delegates to WRB calcic).

Usage

```
calcic_horizon_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`calcic_subgroup_usda` *Calcic Subgroup helper – delegates to calcic_horizon_usda within* `max_top_cm`*.*

Description

Calcic Subgroup helper – delegates to calcic_horizon_usda within `max_top_cm`.

Usage

```
calcic_subgroup_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

cambic *Cambic horizon (WRB 2022)*

Description

Tests whether any horizon meets the cambic horizon criteria. The cambic horizon is a subsurface horizon with evidence of pedological alteration that does not meet the criteria for any stronger diagnostic horizon. It is the diagnostic of Cambisols.

Usage

```
cambic(pedon, min_thickness = 15, min_top_cm = 5, engine = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness in cm (default 15).
`min_top_cm`	Minimum top depth (cm) for a horizon to be considered cambic-eligible (default 5). Anchors the candidate set to subsurface layers.
`engine`	v0.9.63+. One of `"soilkey"` (hand-coded path, default for back-compat) or `"aqp"` (canonical NRCS dispatch via `aqp::getCambicBounds`). When `NULL` (the new default) the function reads `getOption("soilKey.diagnostic_engine", "soilkey")`, so a global `options(soilKey.diagnostic_engine = "aqp")` flips every `cambic()` call without modifying call sites. The aqp engine fired 40.6 soilkey 0 v0.9.50 LUCAS WRB benchmark from 0 100 `cambic_aqp`.

Details

v0.2 implementation tests three conditions:

- thickness >= 15 cm (`test_minimum_thickness`)
- texture sandy loam or finer (`test_texture_argic`)
- NOT `argic` AND NOT `ferralic`

v0.2 limitations: WRB 2022 also excludes profiles with spodic, calcic, gypsic, plinthic, vertic, and several other diagnostic horizons. Those exclusions, plus the WRB criteria of "evidence of alteration" (color/structure differences from parent material, carbonate removal), are scheduled for v0.3.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 3, Cambic horizon.

cambic_aqp *Cambic horizon via aqp::getCambicBounds()*

Description

Wraps `aqp::getCambicBounds()` in soilKey's `DiagnosticResult` contract. The aqp test enforces the KST 13ed cambic criteria:

- Texture finer than loamy fine sand (i.e. NOT in the sandy-texture pattern).
- Soil structure or absence of rock structure.
- Evidence of pedogenic alteration (chroma / value / clay).
- NOT meeting argic / oxic / spodic / mollic criteria.

soilKey's `cambic` (and the SiBCS proxy `B_incipiente`) implements similar logic but with SiBCS / WRB-flavoured exclusions; the aqp engine here is an independent canonical reference.

Usage

```
cambic_aqp(pedon, argi_bounds = NULL, ...)
```

Arguments

`pedon`	A `PedonRecord`.
`argi_bounds`	Optional `c(ubound, lbound)` for argillic bounds (forwarded to aqp). `NULL` (default) means the aqp internals re-detect.
`...`	Reserved for future arguments.

Value

A `DiagnosticResult` with name = `"cambic_aqp"`.

See Also

`cambic` (soilKey hand-coded), `aqp::getCambicBounds`.

cambissolo *Cambissolos (SiBCS Cap 4, p 113; conceito Cap 3, p 88-89)*

Description

Horizonte B incipiente imediatamente abaixo de A ou histico < 40 cm, com plintita/petroplintita (se presente) que NAO satisfaca aos requisitos para Plintossolos.

Usage

```
cambissolo(pedon)
```

Arguments

pedon	A PedonRecord.

cambissolo_fluvico *Cambissolos Fluvicos (Cap 6): carater fluvico.*

Description

Cambissolos Fluvicos (Cap 6): carater fluvico.

Usage

```
cambissolo_fluvico(pedon)
```

Arguments

pedon	A PedonRecord.

cambissolo_haplico *Cambissolos Haplicos (catch-all).*

Description

Cambissolos Haplicos (catch-all).

Usage

```
cambissolo_haplico(pedon)
```

Arguments

pedon	A PedonRecord.

`cambissolo_histico` *Cambissolos Histicos (Cap 6): horizonte histico sem espessura para Organossolo.*

Description

Cambissolos Histicos (Cap 6): horizonte histico sem espessura para Organossolo.

Usage

```
cambissolo_histico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`cambissolo_humico` *Cambissolos Humicos (Cap 6): horizonte A humico.*

Description

Cambissolos Humicos (Cap 6): horizonte A humico.

Usage

```
cambissolo_humico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`canonicalise_kst13ed_gg` *Canonicalise a USDA Great Group label to a KST 13ed-compatible key*

Description

Maps both obsolete (pre-KST 13ed) and modern Great Group names to a single canonical key, so that direct equality between predicted and reference Great Group names ignores edition-driven renaming. Names that have no known mapping pass through unchanged.

Usage

```
canonicalise_kst13ed_gg(gg)
```

Arguments

gg	Character vector of Great Group names (lower case, no whitespace).

Details

Examples of the canonicalisation (each pair is rendered equivalent):

- "haplaquolls" (KST 8) === "endoaquolls" (KST 13ed)
- "pellusterts" (KST 8) === "hapluderts" (KST 13ed)
- "camborthids" (KST 8) === "haplocambids" (KST 13ed)
- "vitrandepts" (KST 8) === "vitrudands" (KST 13ed)

Value

Character vector of canonical keys. Unmapped names pass through. NA stays NA. Empty input returns empty vector.

References

Soil Survey Staff (2022), Keys to Soil Taxonomy 13ed, Ch 4 (Order keys); previous editions for the obsolete names.

---

canonical_reference *Load a canonical reference dataset from soilKey or SoilTaxonomy*

Description

Resolution order:

1. If the SoilTaxonomy package is installed AND the prefer_pkg argument is TRUE (default), load the dataset from the installed package (always fresh).
2. Otherwise, load from the vendored copy at inst/extdata/canonical/<name>.rda.

Usage

```
canonical_reference(
  name = c("WRB_4th_2022", "ST_criteria_13th", "ST_features"),
  prefer_pkg = TRUE
)
```

Arguments

name	One of "WRB_4th_2022", "ST_criteria_13th", "ST_features".
prefer_pkg	If TRUE (default), prefer the installed SoilTaxonomy package over the vendored copy. Set to FALSE to force the vendored copy (e.g. for reproducibility of a specific soilKey release).

Value

The dataset as the original R object (list or data.frame).

See Also

wrb2022_canonical, kst13_canonical, st_features_canonical.

`carater_acrico` *Carater acrico (SiBCS Cap 1, p 31)*

Description

Indica solos com balanca de cargas predominante eletropositiva ou eletricamente neutra. Discrimina Latossolos Acricos / Acriferricos no 3o nivel (Cap 10).

Usage

```
carater_acrico(pedon, max_ecec_clay = 1.5, min_delta_ph = 0)
```

Arguments

`pedon`	A PedonRecord.
`max_ecec_clay`	Limite superior de CECef/argila em cmolc/kg argila (default 1.5).
`min_delta_ph`	Limite inferior de ΔpH (default 0).

Details

Criterios canonicos (todos verificados em horizontes B):

1. $\Delta pH = pH(KCl) - pH(H_2O) \geq 0$ 2. CECef por kg de argila $\leq$ 1.5 cmolc/kg argila

Value

DiagnosticResult; `passed` = `TRUE` se pelo menos um horizonte B satisfaz ambos os criterios.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 31; Cap 10 (Latossolos), pp 173-176.

`carater_alitico` *Carater alitico (SiBCS Cap 1, p 32)*

Description

Critérios canônicos: Al(extr) >= 4 cmolc/kg solo, saturacao por aluminio [100 * Al / (S + Al)] >= 50%, e saturacao por bases V < 50%. Avaliado no horizonte B (ou C, na ausencia de B).

Usage

```
carater_alitico(pedon, min_al = 4, min_al_sat = 50, max_v = 50)
```

Arguments

pedon	A PedonRecord.
min_al	Numeric threshold or option (see Details).
min_al_sat	Numeric threshold or option (see Details).
max_v	Numeric threshold or option (see Details).

`carater_arenico` *Carater arenico (SiBCS Cap 5)*

Description

Solos com textura arenosa (clay% < `max_clay_pct`, default 15%) desde a superficie ate uma profundidade entre `min_depth_cm` e `max_depth_cm` (default 50-100 cm). Discrimina os Subgrupos arenicos de Argissolos (Cap 5: PAC, PA, PV, PVA) e Neossolos (Cap 12).

Usage

```
carater_arenico(
  pedon,
  max_clay_pct = 15,
  min_depth_cm = 50,
  max_depth_cm = 100
)
```

Arguments

pedon	A PedonRecord.
max_clay_pct	Limite superior de % argila para "arenoso" (default 15 = areia / areia franca).
min_depth_cm	Profundidade minima do boundary (default 50).
max_depth_cm	Profundidade maxima do boundary (default 100).

Details

Implementacao: ordena horizontes por top_cm, identifica o PRIMEIRO horizonte com clay_pct >= max_clay_pct, e verifica que (a) todos os horizontes acima desse boundary sao arenosos (sem camada argilosa intercalada acima) e (b) o boundary (top_cm) cai no intervalo [min_depth_cm,max_depth_cm].

Para "espessarenicos" (boundary 100-200 cm), use carater_espessarenico (planejado v0.7.4.B.3).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5 (Argissolos), pp 120-138.

---

carater_argiluvico — *Carater argiluvico (SiBCS Cap 1; Cap 6)*

Description

Solos com B textural (B_textural) em posicao NAO diagnostica para Argissolos, dentro de max_depth_cm. Discrimina os Subgrupos argissolicos de Cambissolos (Cap 6 CX 4.7.8, 4.10.5).

Usage

```
carater_argiluvico(pedon, max_depth_cm = 150)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Default 150 cm.

Details

Implementacao v0.7.5: requer B_textural passa em alguma camada com top_cm < max_depth_cm. Distingue-se de Argissolo pleno por contexto: chamado dentro de Cambissolos onde B incipiente (B_incipiente) ja definiu a ordem como Cambissolo.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 1; Cap 6, p 153.

carater_cambissolico *Carater cambissolico (SiBCS Cap 14)*

Description

Solos com B incipiente (B_incipiente) abaixo do horizonte hístico (H/O) ou A. Discrimina os Subgrupos cambissolicos de Organossolos Folicos (Cap 14, pp 247-248): Folicos Fibricos / Hemicos / Sapricos cambissolicos.

Usage

```
carater_cambissolico(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementado como uma interseccao de duas condicoes:

1. `B_incipiente` passa em ao menos um horizonte
2. Esse horizonte B incipiente esta abaixo de um horizonte H/O (hístico) ou A

Em pedons sem H/O ou A acima do B incipiente, o teste falha (B incipiente isolado nao caracteriza Organossolo Cambissolico).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 14, pp 247-248.

carater_cambissolico_arg *Carater cambissolico (Argissolos – Cap 5)*

Description

Solos com 4% ou mais de minerais alteraveis visiveis E/OU 5% ou mais de fragmentos de rocha (`coarse_fragments_pct`) no horizonte B (exclusive BC ou B/C), dentro de `max_depth_cm`. Discrimina os Subgrupos cambissolicos de Argissolos PA (Cap 5, p 126) – DISTINTO do carater_cambissolico (Cap 14 Organossolos Folicos: B incipiente abaixo de histico/A).

Usage

```
carater_cambissolico_arg(pedon, min_coarse_pct = 5, max_depth_cm = 150)
```

Arguments

pedon	A PedonRecord.
min_coarse_pct	Default 5% volume.
max_depth_cm	Default 150 cm.

Details

Implementacao v0.7.4 (aproximacao): apenas `coarse_fragments_pct` $\geq$ `min_coarse_pct` (default 5) eh testado. O criterio "minerais alteraveis visiveis" exigiria campo adicional no schema (e.g. `weatherable_minerals_pct`) que sera adicionado em release futura. Documentado como limitacao conhecida.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, p 126.

---

carater_carbonatico   *Carater carbonatico (SiBCS Cap 1, p 33)*

Description

>= 150 g/kg (15%) de CaCO3 equivalente em qualquer forma de segregacao (incl. nodulos, concrecoes). Excludente: nao satisfaz aos requisitos de horizonte calcico.

Usage

```
carater_carbonatico(pedon, min_caco3_pct = 15, max_depth_cm = NULL)
```

Arguments

pedon	A PedonRecord.
min_caco3_pct	Limite de CaCO3 (default 15%).
max_depth_cm	Profundidade maxima (`top_cm`) em que camadas qualificam (default `NULL` = sem restricao). SiBCS Cap 14 Subgrupos usam `max_depth_cm = 150`.

carater_chernossolico *Carater chernossolico (SiBCS Cap 5; A chernozemico + Ta alta)*

Description

Solos com horizonte A chernozemico (horizonte_A_chernozemico) E atividade da argila ≥ min_ta (default 20 cmolc/kg argila) na maior parte dos primeiros 100 cm do B (inclusive BA). Discrimina os Subgrupos chernossolicos de Argissolos (Cap 5: PV, PVA).

Usage

```
carater_chernossolico(pedon, min_ta = 20)
```

Arguments

pedon	A PedonRecord.
min_ta	Threshold de atividade da argila (default 20).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, p 134; Cap 7 (Chernossolos).

carater_coeso *Carater coeso (SiBCS Cap 1, pp 32-33)*

Description

Solos com horizontes coesos: muito duros a extremamente duros quando secos, friaveis a firmes quando umidos, decorrentes do empacotamento das particulas e/ou cimentacao. Discrimina os Grandes Grupos Distrocoesos / Eutrocoesos de Argissolos (Cap 5, pp 117-119) e Latossolos (Cap 10).

Usage

```
carater_coeso(pedon, max_depth_cm = 150)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade maxima onde camadas qualificam (default 150, conforme SiBCS Cap 5: "dentro de 150 cm a partir da superficie").

Details

Criterios canonicos:

- `rupture_resistance` $\in$ {"very hard", "extremely hard"} (em estado seco)
- `consistence_moist` $\in$ {"friable", "firm"} (em estado umido)
- Excluido: textura areia / areia franca (`clay_pct` < 15%)

Value

`DiagnosticResult`; `passed = TRUE` se ao menos uma camada (com textura suficiente) atende aos dois criterios de consistencia.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, pp 32-33; Cap 5 (Argissolos), pp 117-119.

`carater_durico` *Carater durico (SiBCS Cap 1)*

Description

Solos com endurecimento por cimentacao parcial de silica (SiO2), insuficiente para qualificar como horizonte durico (`duripa`) completo. Detectado quando:

Usage

```
carater_durico(pedon, max_depth_cm = 150)
```

Arguments

`pedon`	A `PedonRecord`.
`max_depth_cm`	Profundidade maxima onde camadas qualificam (default 150, conforme SiBCS Cap 5: "dentro de 150 cm").

Details

- `duripan_pct` > 0 (presenca de noduros / concrecoes de silica), OR
- `cementation_class` $\in$ {"weakly", "moderately"} (cimentacao fraca a moderada, NAO indurada/strongly).

Discrimina os Subgrupos duricos / abrupticos duricos de Argissolos Acinzentados (Cap 5 PAC) e Latossolos com caracter durico (Cap 10).

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1; Cap 5 (Argissolos Acinzentados Distrocoesos abrupticos duricos), p 120.

`carater_ebanico` *Carater ebanico (SiBCS Cap 1; Cap 7 e Cap 17)*

Description

Cor preta uniforme (value $\leq$ 3 e chroma $\leq$ 2 em umido) em TODO o horizonte B + atividade da argila alta (Ta) + saturacao por bases V% $\geq$ 65. Discrimina Chernossolos Ebanicos (Cap 7) e Vertissolos Ebanicos (Cap 17) no 2o nivel.

Usage

```
carater_ebanico(pedon, max_value = 3, max_chroma = 2, min_v = 65)
```

Arguments

`pedon`	A `PedonRecord`.
`max_value`	Limite superior de Munsell value em umido (default 3).
`max_chroma`	Limite superior de chroma em umido (default 2).
`min_v`	Limite inferior de V% (default 65).

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1; Cap 7 (Chernossolos), pp 144-148; Cap 17 (Vertissolos), pp 271-274.

`carater_espessarenico` *Carater espessarenico (SiBCS Cap 5)*

Description

Textura arenosa (clay% < `max_clay_pct`) da superficie ate boundary em [100, 200] cm. Variante "espessa" do `carater_arenico`.

Usage

```
carater_espessarenico(
  pedon,
  max_clay_pct = 15,
  min_depth_cm = 100,
  max_depth_cm = 200
)
```

Arguments

pedon	A PedonRecord.
max_clay_pct	Limite superior de % argila (default 15).
min_depth_cm	Profundidade minima do boundary (default 100).
max_depth_cm	Profundidade maxima do boundary (default 200).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, pp 130-131.

---

carater_espodico — *Carater espodico (SiBCS Cap 1, p 35; Cap 8)*

Description

Evidencia iluvial de Al / Fe / materia organica em camada de pelo menos 2,5 cm de espessura, em quantidade insuficiente para qualificar como horizonte B espodico (B_espodico), mas suficiente para indicar espodicidade incipiente. Usado em Cambissolos / Argissolos / Plintossolos espodicos (Caps 5, 6 e 16) e em Espodossolos rasos (Cap 8).

Usage

```
carater_espodico(pedon, min_thickness = 2.5, min_oc_pct = 0.5)
```

Arguments

pedon	A PedonRecord.
min_thickness	Espessura minima da camada espodica incipiente em cm (default 2,5).
min_oc_pct	OC% minimo em camada candidata (default 0,5).

Details

Diferenca para B_espodico: thickness >= 2,5 cm em vez de exigir o gate completo de espessura espodica; OC >= 0,5% em vez do gate de iluviacao quantitativa; sinais de iluviacao Fe/Al (al_ox_pct ou fe_ox_pct ou fe_dcb_pct).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 35; Cap 8 (Espodossolos), pp 156-160.

---

carater_espodico_profundo

Carater B espodico profundo (SiBCS Cap 8)

Description

Solos com horizonte B espodico cujo top_cm esta entre min_top_cm (default 200) e max_top_cm (default 400). Discrimina os Grandes Grupos Hiperespessos / Hidro-hiperespessos de Espodossolos (Cap 8 1.1, 1.3, 2.1, 2.3, 3.1, 3.3).

Usage

```
carater_espodico_profundo(pedon, min_top_cm = 200, max_top_cm = 400)
```

Arguments

pedon	A PedonRecord.
min_top_cm	Default 200.
max_top_cm	Default 400.

Details

Implementacao: chama carater_espodico e filtra por top_cm no intervalo [min_top_cm, max_top_cm].

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 8, pp 165-168.

carater_eutrico *Carater eutrico (SiBCS Cap 1, p 35)*

Description

Distinto de "eutrofico": exige pH(H2O) >= 5.7 conjugado com S (soma de bases) >= 2.0 cmolc/kg solo dentro da secao de controle.

Usage

```
carater_eutrico(pedon, min_pH = 5.7, min_s = 2)
```

Arguments

pedon	A PedonRecord.
min_pH	Numeric threshold or option (see Details).
min_s	Numeric threshold or option (see Details).

carater_ferrico *Carater ferrico (SiBCS Cap 1, p 35; Cap 5 e Cap 10)*

Description

Teor de Fe2O3 (pelo ataque sulfurico-NaOH) entre 180 e 360 g/kg de solo (= 18%-36% mass) na maior parte dos primeiros 100 cm do horizonte B. Acima de 360 g/kg = "perferrico" (nao implementado aqui). Discrimina os Grandes Grupos Eutroferricos / Distroferricos / Aluminoferricos de Latossolos (Cap 10), Argissolos (Cap 5 Eutroferricos) e Cambissolos (Cap 6 Aluminoferricos).

Usage

```
carater_ferrico(
  pedon,
  min_fe2o3_pct = 18,
  max_fe2o3_pct = 36,
  max_depth_cm = 100
)
```

Arguments

pedon	A PedonRecord.
min_fe2o3_pct	Limite inferior de Fe2O3 sulfurico em % mass (default 18 = 180 g/kg).
max_fe2o3_pct	Limite superior (exclusivo) em % mass (default 36 = 360 g/kg).
max_depth_cm	Profundidade maxima de B avaliado (default 100).

Details

Implementacao v0.7.4: testa se *algum* horizonte B dentro de `max_depth_cm` atende ao intervalo. SiBCS estrito ("na maior parte de") seria uma media ponderada por espessura – refinamento planejado para v0.7.5.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 35; Cap 5 (Argissolos Eutroferricos, p 118); Cap 10 (Latossolos).

`carater_fluvico` *Carater fluvico (SiBCS Cap 1, p 35-36): camadas estratificadas + distribuicao irregular de C organico. Reuso de fluvic_material (WRB).*

Description

Carater fluvico (SiBCS Cap 1, p 35-36): camadas estratificadas + distribuicao irregular de C organico. Reuso de fluvic_material (WRB).

Usage

```
carater_fluvico(pedon)
```

Arguments

pedon	A `PedonRecord`.

`carater_gleissolico` *Carater gleissolico (SiBCS Cap 5; horizonte_glei em posicao nao-Gleissolo)*

Description

Solos com horizonte glei (`horizonte_glei`) em posicao nao diagnostica para Gleissolos (i.e., dentro de `max_depth_cm` mas NAO satisfazendo os requisitos completos de Gleissolo). Discrimina os Subgrupos gleissolicos de Argissolos (Cap 5 PA), Cambissolos (Cap 6) e outros.

Usage

```
carater_gleissolico(pedon, max_depth_cm = 150)
```

Arguments

pedon A PedonRecord.
max_depth_cm Profundidade maxima onde camadas qualificam (default 150).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, p 126; Cap 9 (Gleissolos).

---

carater_hidromorfico *Carater hidromorfico (SiBCS Cap 8)*

Description

Solos saturados com agua em camada(s) dentro de max_depth_cm (default 100 cm), evidenciado por horizonte glei (horizonte_glei) OU caracter redoxico (carater_redoxico) OU horizonte Eg na designation OU acumulacao de Mn em horizonte E ou B espodico. Discrimina os Grandes Grupos Hidromorficos / Hidro-hiperespessos de Espodossolos (Cap 8 1.1, 1.2, 2.1, 2.2, 3.1, 3.2).

Usage

```
carater_hidromorfico(pedon, max_depth_cm = 100)
```

Arguments

pedon A PedonRecord.
max_depth_cm Default 100 cm.

Details

Implementacao v0.7.5 (aproximacao):

- horizonte_glei dentro de max_depth_cm, OR
- carater_redoxico ate max_depth_cm, OR
- designation pattern Eg dentro de max_depth_cm.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 8, pp 165-168.

---

carater_hipocarbonatico
Carater hipocarbonatico (SiBCS Cap 1, p 33): CaCO3 entre 50 e 150 g/kg.

Description

Carater hipocarbonatico (SiBCS Cap 1, p 33): CaCO3 entre 50 e 150 g/kg.

Usage

```
carater_hipocarbonatico(pedon, max_depth_cm = NULL)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade maxima em que camadas qualificam (default NULL = sem restricao). SiBCS Cap 14 Subgrupos de Organossolos Haplicos Sapricos usam max_depth_cm = 150.

---

carater_humico_espesso
Carater espesso-humico (SiBCS Cap 5, p 119)

Description

Solos com horizonte A humico e conteudo de carbono >= min_oc_pct (default 1% = 10 g/kg) extendendo-se ate min_depth_cm (default 80 cm) ou mais de profundidade. Discrimina os Subgrupos "espesso-humicos" de Argissolos Bruno-Acinzentados Ta Aluminicos (Cap 5 PBAC 1.1.2) – camadas humosas espessas tipicas de Argissolos do RS.

Usage

```
carater_humico_espesso(pedon, min_oc_pct = 1, min_depth_cm = 80)
```

Arguments

pedon	A PedonRecord.
min_oc_pct	Limite inferior de OC% nas camadas inferiores (default 1.0 = 10 g/kg).
min_depth_cm	Profundidade minima de extensao do C alto (default 80 cm).

Details

Implementacao: requer (1) horizonte_A_humico passa AND (2) ha camada com oc_pct >= min_oc_pct cuja bottom_cm >= min_depth_cm.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5 (Argissolos), p 119.

---

carater_latossolico   *Carater latossolico (SiBCS Cap 5)*

Description

Solos com horizonte B latossolico (B_latossolico) abaixo do horizonte B textural (B_textural), dentro de max_depth_cm (default 150 cm). Discrimina os Subgrupos latossolicos de Argissolos (Cap 5: PAC, PA, PV, PVA) – transicao entre Argissolo e Latossolo dentro do mesmo perfil.

Usage

```
carater_latossolico(pedon, max_depth_cm = 150)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade maxima do B latossolico (default 150).

Details

Implementacao: requer (1) B_textural() passa, (2) B_latossolico() passa, e (3) ao menos uma camada com B latossolico tem top_cm maior que o top_cm maximo das camadas com B textural (i.e., latossolico ocorre abaixo).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5 (Argissolos), pp 121-138.

carater_leptico *Carater leptico (SiBCS Cap 5; contato litico em 50-100 cm)*

Description

Solos com contato litico (contato_litico) a profundidade entre 50 e 100 cm. Discrimina os Subgrupos lepticos de Argissolos (Cap 5: PA, PV, PVA).

Usage

```
carater_leptico(pedon, min_depth_cm = 50, max_depth_cm = 100)
```

Arguments

pedon	A PedonRecord.
min_depth_cm	Default 50.
max_depth_cm	Default 100.

Details

Implementacao: chama `contato_litico(pedon)` sem bound, depois filtra layers para top em [`min_depth_cm`, `max_depth_cm`].

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, pp 127, 132.

carater_leptofragmentario *Carater leptofragmentario (SiBCS Cap 5; Cr / fragmentary 50-100 cm)*

Description

Solos com contato litico fragmentario (Cr / Crf) a profundidade entre 50 e 100 cm. Discrimina os Subgrupos leptofragmentarios de Argissolos (Cap 5: PA, PV, PVA).

Usage

```
carater_leptofragmentario(pedon, min_depth_cm = 50, max_depth_cm = 100)
```

Arguments

pedon	A PedonRecord.
min_depth_cm	Default 50.
max_depth_cm	Default 100.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, pp 127, 132.

---

carater_luvissolico *Carater luvissolico (SiBCS Cap 5; Ta + S alta)*

Description

Solos com atividade da argila ≥ min_ta (default 20 cmolc/kg argila) E soma de bases (S) ≥ min_s (default 5 cmolc/kg solo), ambos na maior parte dos primeiros 100 cm do horizonte B. Discrimina os Subgrupos luvissolicos de Argissolos (Cap 5: PV, PVA).

Usage

```
carater_luvissolico(pedon, min_ta = 20, min_s = 5, max_depth_cm = 100)
```

Arguments

pedon	A PedonRecord.
min_ta	Threshold de atividade da argila em cmolc/kg argila (default 20).
min_s	Threshold de S em cmolc/kg solo (default 5).
max_depth_cm	Profundidade maxima de B avaliado (default 100).

Details

Note: o threshold de Ta para "luvissolico" e 20 (vs 27 para atividade_argila_alta canonico). S = Ca + Mg + K + Na trocaveis.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, p 134; Cap 11 (Luvissolos).

carater_nitossolico *Carater nitossolico (SiBCS Cap 5)*

Description

Solos com morfologia (estrutura e cerosidade) semelhante aos Nitossolos, mas diferindo por apresentar relacao textural B/A $>$ 1,5 OU policromia (multiplas matizes Munsell em horizontes B) dentro de `max_depth_cm` cm. Discrimina os Subgrupos nitossolicos de Argissolos (Cap 5: PV, PVA).

Usage

```
carater_nitossolico(pedon, max_b_a_ratio = 1.5, max_depth_cm = 150)
```

Arguments

`pedon`	A `PedonRecord`.
`max_b_a_ratio`	Razao maxima B/A para Nitossolos (default 1.5); Argissolos nitossolicos tem ratio > 1.5.
`max_depth_cm`	Profundidade maxima do B avaliado (default 150).

Details

Implementacao v0.7.4 (aproximacao):

- `cerosidade` $\geq$ comum + moderada, AND
- Razao textural B/A > `max_b_a_ratio` (default 1.5), OR policromia ($\geq$ 2 matizes distintos em B).

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, pp 129-131; Cap 13.

`carater_palico` *Carater palico (SiBCS Cap 11)*

Description

Solos com espessura do solum (A + B, inclusive E e exclusive BC) maior que `min_solum_cm` (default 80). Discrimina os Grandes Grupos Palicos de Luvissolos (Cap 11 TCp, TXp) – "desenvolvimento excessivo" (do latim "pale").

Usage

```
carater_palico(pedon, min_solum_cm = 80)
```

Arguments

`pedon`	A `PedonRecord`.
`min_solum_cm`	Default 80.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 11, p 214.

`carater_perferrico` *Carater perferrico (SiBCS Cap 1; Cap 6 CX Perferricos)*

Description

Teor de Fe2O3 (pelo ataque sulfurico-NaOH) >= 360 g/kg de solo (= 36%) na maior parte dos primeiros 100 cm do horizonte B. Discrimina os Grandes Grupos Perferricos (acima do range "ferrico" 180-360 g/kg). Cap 6 CX 4.3 e Cap 10 (Latossolos Perferricos).

Usage

```
carater_perferrico(pedon, min_fe2o3_pct = 36, max_depth_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`min_fe2o3_pct`	Limite inferior em % mass (default 36 = 360 g/kg).
`max_depth_cm`	Profundidade maxima de B avaliado (default 100).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 1; Cap 6, p 142; Cap 10 (Latossolos Perferricos).

---

carater_petroplintico *Carater petroplintico (SiBCS Cap 5)*

Description

Caracteres concrecionario e/ou litoplintico ou horizontes concrecionario / litoplintico em posicao NAO diagnostica para Plintossolos Petricos, dentro de `max_depth_cm` (default 150). Discrimina os Subgrupos petroplinticos de Argissolos (Cap 5: PA, PVA, PV).

Usage

```
carater_petroplintico(pedon, max_depth_cm = 150)
```

Arguments

`pedon`	A PedonRecord.
`max_depth_cm`	Default 150 cm.

Details

Implementacao: passa se `horizonte_concrecionario` OU `horizonte_litoplintico` retornarem TRUE em ao menos uma camada com top < max_depth_cm.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5; Cap 16 (Plintossolos).

`carater_placico` *Carater placico (SiBCS Cap 5; horizonte placico cementado por Fe/Mn)*

Description

Camada cimentada por Fe/Mn (geralmente fina, 1-25 mm), detectada via `cementation_class %in% {"strongly", "indurated"}` dentro de `max_depth_cm`. Discrimina os Subgrupos placicos de Argissolos PA (Cap 5).

Usage

```
carater_placico(pedon, max_depth_cm = 150)
```

Arguments

`pedon`	A `PedonRecord`.
`max_depth_cm`	Default 150 cm.

Details

Implementacao v0.7.4 (aproximacao): `cementation_class` forte ou indurada. SiBCS estrito requeria espessura minima e composicao Fe/Mn confirmada. Refinamento planejado para v0.8.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, p 125.

`carater_planossolico` *Carater planossolico (SiBCS Cap 5)*

Description

Caracter planico em posicao NAO diagnostica para Planossolos. Discrimina os Subgrupos planossolicos de Argissolos (Cap 5: PA, PVA, PV).

Usage

```
carater_planossolico(pedon, max_depth_cm = 150)
```

Arguments

pedon A PedonRecord.

max_depth_cm Profundidade maxima (default 150).

Details

Implementacao v0.7.4: aproxima como B_planico OR (mudanca_textural_abrupta AND carater_sodico). SiBCS Cap 1 estritamente define caracter planico via mudanca textural abrupta + horizonte/caracter sodico em B + cores neutras.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 5; Cap 1, p 36; Cap 15 (Planossolos).

---

carater_plintico *Carater plintico (SiBCS Cap 1, p 36): plintita >= 5% em quantidade insuficiente para horizonte plintico.*

Description

Carater plintico (SiBCS Cap 1, p 36): plintita >= 5% em quantidade insuficiente para horizonte plintico.

Usage

```
carater_plintico(pedon, min_plinthite_pct = 5, max_plinthite_pct = 15)
```

Arguments

pedon A PedonRecord.

min_plinthite_pct
Numeric threshold or option (see Details).

max_plinthite_pct
Numeric threshold or option (see Details).

carater_psamitico — *Carater psamitico (SiBCS Cap 10)*

Description

Solos com conteudo de argila inferior a `max_clay_pct` (default 20% = 200 g/kg) na maior parte dos primeiros `max_depth_cm` (default 150 cm) a partir da superficie do solo. Discrimina os Subgrupos psamiticos de Latossolos Amarelos Distroficos (Cap 10 LA 2.6.1).

Usage

```
carater_psamitico(pedon, max_clay_pct = 20, max_depth_cm = 150)
```

Arguments

`pedon`	A `PedonRecord`.
`max_clay_pct`	Default 20% = 200 g/kg.
`max_depth_cm`	Default 150 cm.

Details

Implementacao: testa se a media ponderada por espessura de `clay_pct` dentro de [0, max_depth_cm] esta abaixo de max_clay_pct.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 10 LA, p 203.

carater_redoxico — *Carater redoxico (SiBCS Cap 1, p 36-37): feicoes redoximorficas em quantidade pelo menos comum, dentro da secao de controle.* `epirredoxico` *se dentro de 50 cm;* `endorredoxico` *se 50-150 cm.*

Description

Carater redoxico (SiBCS Cap 1, p 36-37): feicoes redoximorficas em quantidade pelo menos comum, dentro da secao de controle. `epirredoxico` se dentro de 50 cm; `endorredoxico` se 50-150 cm.

Usage

```
carater_redoxico(pedon, min_redox_pct = 5, max_top_cm = 150)
```

Arguments

`pedon`	A `PedonRecord`.
`min_redox_pct`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).

`carater_retratil` *Carater retratil (SiBCS Cap 1, p 33)*

Description

Solos com retracao significativa quando secos: COLE $\geq$ 0,06 sobre a secao de controle, OU presenca de slickensides + fendas (cracks) suficientemente desenvolvidas. Discrimina Cambissolos retrateis (Cap 6), Vertissolos (Cap 17) e Argissolos retrateis (Cap 5).

Usage

```
carater_retratil(pedon, min_cole = 0.06, min_crack_width = 1)
```

Arguments

`pedon`	A `PedonRecord`.
`min_cole`	Limite inferior de COLE (default 0,06).
`min_crack_width`	Largura minima de fenda em cm para o caminho slickensides+cracks (default 1).

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 33.

carater_rubrico *Carater rubrico (SiBCS Cap 1; Cap 10 Latossolos Brunos)*

Description

Solos com matiz Munsell mais vermelho que 5YR (i.e., 2.5YR, 10R, 5R) E chroma $\geq$ 4 em alguma parte do horizonte B (inclusive BA), dentro de `max_depth_cm` (default 100). Discrimina os Subgrupos rubricos de Latossolos Brunos (Cap 10 LB).

Usage

```
carater_rubrico(pedon, min_chroma = 4, max_depth_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`min_chroma`	Default 4.
`max_depth_cm`	Default 100.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1; Cap 10 LB, p 199-200.

carater_salico *Carater salico (SiBCS Cap 1, p 38): CE >= 7 dS/m em alguma epoca.*

Description

Carater salico (SiBCS Cap 1, p 38): CE >= 7 dS/m em alguma epoca.

Usage

```
carater_salico(pedon, min_ec = 7, max_depth_cm = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`min_ec`	Limite de CE em dS/m (default 7).
`max_depth_cm`	Profundidade maxima em que camadas qualificam (default `NULL`). SiBCS Cap 14 Subgrupos usam 150.

`carater_salino` *Carater salino (SiBCS Cap 1, p 39): 4 <= CE < 7 dS/m.*

Description

Carater salino (SiBCS Cap 1, p 39): 4 <= CE < 7 dS/m.

Usage

```
carater_salino(pedon, min_ec = 4, max_ec = 7, max_depth_cm = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`min_ec`	Limite inferior de CE em dS/m (default 4).
`max_ec`	Limite superior (exclusivo) (default 7).
`max_depth_cm`	Profundidade maxima em que camadas qualificam (default `NULL`). SiBCS Cap 14 Subgrupos usam 150.

`carater_saprolitico` *Carater saprolitico (SiBCS Cap 5)*

Description

Solos com horizonte Cr (brando) e ausencia de contato litico ou litico fragmentario, todos dentro de `max_depth_cm` (default 100 cm). Discrimina os Subgrupos saproliticos de Argissolos (Cap 5: PA, PV).

Usage

```
carater_saprolitico(pedon, max_depth_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_depth_cm`	Default 100.

Details

Implementacao: requer (a) designation pattern `Cr/Crf` (sem `R` continuo) em camada com `top` < `max_depth_cm`, e (b) `contato_litico(pedon)` retorna FALSE.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 5, pp 122, 132.

`carater_sodico` *Carater sodico (SiBCS Cap 1, p 39): saturacao por sodio (PST) >= 15%.*

Description

Carater sodico (SiBCS Cap 1, p 39): saturacao por sodio (PST) >= 15%.

Usage

```
carater_sodico(pedon, min_pst = 15, max_depth_cm = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`min_pst`	PST minimo (%) (default 15).
`max_depth_cm`	Profundidade maxima em que camadas qualificam (default `NULL`). SiBCS Cap 14 Subgrupos usam 150.

`carater_solodico` *Carater solodico (SiBCS Cap 1, p 39): PST entre 6% e < 15%.*

Description

Carater solodico (SiBCS Cap 1, p 39): PST entre 6% e < 15%.

Usage

```
carater_solodico(pedon, min_pst = 6, max_pst = 15, max_depth_cm = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`min_pst`	PST minimo (%) (default 6).
`max_pst`	PST maximo (%) (default 15).
`max_depth_cm`	Profundidade maxima em que camadas qualificam (default `NULL`). SiBCS Cap 14 Subgrupos usam 150.

`carater_sombrico` *Carater sombrico (SiBCS Cap 1; Cap 5 PV)*

Description

Camada subsuperficial com acumulacao iluvial de materia organica, caracterizada por cores escuras (`munsell_value_moist` $\leq$ 4, `munsell_chroma_moist` $\leq$ 3) e `oc_pct` $\geq$ 0.5%, em B abaixo de A/E. Distinto de B espodico por nao requerer iluviacao Al/Fe. Tipico de solos altitudinais (planaltos sul-brasileiros). Discrimina o Subgrupo sombricos de Argissolos Vermelhos Aluminicos (Cap 5 PV 4.2.6).

Usage

```
carater_sombrico(
  pedon,
  max_value = 4,
  max_chroma = 3,
  min_oc_pct = 0.5,
  max_depth_cm = 150
)
```

Arguments

`pedon`	A `PedonRecord`.
`max_value`	Default 4 (escuro).
`max_chroma`	Default 3.
`min_oc_pct`	Default 0.5%.
`max_depth_cm`	Default 150.

Details

Implementacao v0.7.4 (aproximacao):

- Camada B (`designation` matches `^B`) com value $\leq$ max_value E chroma $\leq$ max_chroma E oc_pct $\geq$ min_oc_pct, dentro de max_depth_cm.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1; Cap 5 PV 4.2.6, p 130 (Lunardi Neto, 2012, perfil PVa).

carater_terrico *Carater terrico (SiBCS Cap 14)*

Description

Solos com horizontes ou camadas constituidos por materiais minerais (horizonte A, Ag, Big e/ou Cg), com espessura cumulativa $\geq$ `min_thickness_cm` dentro de `within_depth_cm` da superficie do solo. Discrimina os Subgrupos terricos de Organossolos (Cap 14, pp 245-250) e Cambissolos terricos (Cap 6).

Usage

```
carater_terrico(pedon, min_thickness_cm = 30, within_depth_cm = 100)
```

Arguments

`pedon` A `PedonRecord`.

`min_thickness_cm`
Espessura cumulativa minima de material mineral (default 30 cm).

`within_depth_cm`
Profundidade de busca (default 100 cm).

Details

Padroes de designacao reconhecidos para horizonte mineral:

- `A`, `Ap`, `An` (mineral superficial)
- `Ag` (mineral hidromorfico)
- `Big`, `Bg` (B mineral hidromorfico)
- `Cg` (C mineral hidromorfico)
- `C`, `Cr`, `Crf` (mineral subsuperficial)

Excluidos do somatorio: horizontes histicos (`H*`, `O*`) e horizontes cementados puros sem material mineral.

Value

`DiagnosticResult`; `passed = TRUE` se a soma da espessura dos horizontes minerais (truncada em `within_depth_cm`) for $\geq$ `min_thickness_cm`.

References

Embrapa (2018), SiBCS 5a ed., Cap 14, p 246 (subgrupos terricos de Organossolos).

carater_tionico *Carater tionico (SiBCS Cap 9; Cap 1 thionic-related)*

Description

Solos com horizonte sulfurico (horizonte_sulfurico) OU materiais sulfidricos a profundidades entre min_depth_cm e max_depth_cm (default 100-150 cm). Discrimina os Subgrupos tionicos de Gleissolos (Cap 9 GZsd, GMtal, GMtd, GXte) – variante "tionico subordinado" (vs Tiomorfico, que e a subordem completa).

Usage

```
carater_tionico(pedon, min_depth_cm = 100, max_depth_cm = 150)
```

Arguments

pedon	A PedonRecord.
min_depth_cm	Default 100 cm.
max_depth_cm	Default 150 cm.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 9, pp 180-191.

carater_vertissolico *Carater vertissolico (SiBCS Cap 6)*

Description

Solos com horizonte vertico OU caracter vertico em posicao nao diagnostica para Vertissolos, dentro de max_depth_cm (default 150). Discrimina os Subgrupos vertissolicos de Cambissolos Carbonaticos / Eutroficos / Tb Eutroferricos (Cap 6 CY 3.1.3, 3.6.2, CX 4.1.5, 4.7.7, 4.11.4).

Usage

```
carater_vertissolico(pedon, max_depth_cm = 150)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Default 150 cm.

Details

Implementacao: passa se `horizonte_vertico` retornar TRUE em ao menos uma camada com `top_cm` < `max_depth_cm`. SiBCS estrito requer "posicao nao diagnostica para Vertissolos" – aproximamos isso confiando no dispatcher (apenas chamamos quando ja sabemos que nao e Vertissolo).

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 6, pp 146-153; Cap 17 (Vertissolos).

`cerosidade` — *Cerosidade quantitativa (SiBCS Cap 13, p 207; Cap 1)*

Description

Diagnostico parametrizado quantidade x intensidade de cerosidade (clay films / cutans). Consume as colunas v0.7.2 `clay_films_amount` (ordinal: few/pouca, common/comum, many/abundante, continuous/continua) e `clay_films_strength` (ordinal: weak/fraca, moderate/moderada, strong/forte; "shiny" mapeado a "strong"), introduzidas em substituicao ao legado `clay_films`.

Usage

```
cerosidade(pedon, min_amount = "common", min_strength = "moderate")
```

Arguments

`pedon`	A `PedonRecord`.
`min_amount`	Quantidade minima: `"few"`, `"common"`, `"many"`, `"continuous"` (ou equivalentes em PT-BR). Default `"common"`.
`min_strength`	Intensidade minima: `"weak"`, `"moderate"`, `"strong"`. Default `"moderate"`. Pass `NULL` para ignorar a dimensao de intensidade.

Details

Discriminante critico Nitossolos vs Argissolos no Cap 13: Nitossolos exigem cerosidade $\geq$ comum + $\geq$ moderada (defaults).

Value

`DiagnosticResult`; `passed = TRUE` se ao menos um horizonte B atende ambos os limiares.

References

Embrapa (2018), SiBCS 5a ed., Cap 13 (Nitossolos), p 207; Cap 1 (atributos diagnosticos).

`chernic` *Chernic horizon (WRB 2022): the cherozemic-style mollic with very high biological activity (worm holes, casts, coprolites). v0.3.3: delegates to mollic + worm_holes_pct >= 50 (proxy for "biological homogenization").*

Description

Chernic horizon (WRB 2022): the cherozemic-style mollic with very high biological activity (worm holes, casts, coprolites). v0.3.3: delegates to mollic + worm_holes_pct >= 50 (proxy for "biological homogenization").

Usage

```
chernic(pedon, min_worm_pct = 50)
```

Arguments

`pedon`	A `PedonRecord`.
`min_worm_pct`	Numeric threshold or option (see Details).

`chernossolo` *Chernossolos (SiBCS Cap 4, p 113; conceito Cap 3, p 89-90)*

Description

A chernozemico seguido de: (a) Bi OR Bt, ambos com argila ativ alta + V alta; OR (b) Bi com espessura < 10 cm OR C, ambos calcicos, petrocalcicos OR carbonaticos; OR (c) Calcico OR carater carbonatico no A, seguido de contato litico / fragmentario.

Usage

```
chernossolo(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`chernossolo_argiluvico` *Chernossolos Argiluvicos (Cap 7): B textural abaixo do A chernozemico.*

Description

Chernossolos Argiluvicos (Cap 7): B textural abaixo do A chernozemico.

Usage

```
chernossolo_argiluvico(pedon)
```

Arguments

pedon	A `PedonRecord`.

`chernossolo_ebanico` *Chernossolos Ebanicos (Cap 7): caracter ebanico em B. v0.7.1: detecta via Munsell em B - hue 7.5YR ou mais amarelo: V<4 + C<3 umido; OR hue mais vermelho 7.5YR: preto/cinza muito escuro.*

Description

Chernossolos Ebanicos (Cap 7): caracter ebanico em B. v0.7.1: detecta via Munsell em B - hue 7.5YR ou mais amarelo: V<4 + C<3 umido; OR hue mais vermelho 7.5YR: preto/cinza muito escuro.

Usage

```
chernossolo_ebanico(pedon)
```

Arguments

pedon	A `PedonRecord`.

chernossolo_haplico *Chernossolos Haplicos (catch-all).*

Description

Chernossolos Haplicos (catch-all).

Usage

```
chernossolo_haplico(pedon)
```

Arguments

pedon	A PedonRecord.

chernossolo_rendzico *Chernossolos Rendzicos (Cap 7): A chernozemico + (calcico/petrocalcico OR carater carbonatico).*

Description

Chernossolos Rendzicos (Cap 7): A chernozemico + (calcico/petrocalcico OR carater carbonatico).

Usage

```
chernossolo_rendzico(pedon)
```

Arguments

pedon	A PedonRecord.

chernozem *Chernozem RSG diagnostic (WRB 2022)*

Description

Tests whether a profile satisfies the Chernozem RSG criteria: a mollic horizon plus secondary carbonates somewhere in the profile, plus chroma (moist) <= 2 in at least one layer of the upper 20 cm.

Usage

```
chernozem(pedon, max_chroma_upper = 2)
```

Arguments

`pedon` A `PedonRecord`.

`max_chroma_upper` Maximum moist chroma in the upper part (default 2, per WRB 2022).

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Chernozems.

---

chernozem_strict — *Chernozem RSG gate (strengthened, WRB 2022 Ch 4, p 111)*

Description

WRB-canonical: chernic horizon AND, starting \<= 50 cm below the lower limit of the mollic horizon and (if a petrocalcic horizon is present) above it, a layer with protocalcic properties \>= 5 cm thick OR a calcic horizon AND base saturation \>= 50% from the surface to the protocalcic / calcic layer throughout.

Usage

```
chernozem_strict(pedon, min_bs = 50, max_top_cm = 50)
```

Arguments

`pedon` A `PedonRecord`.

`min_bs` Numeric threshold or option (see Details).

`max_top_cm` Numeric threshold or option (see Details).

Details

v0.3.4 strengthens the previous v0.2 chernozem (which only required mollic + chernic_color) by adding the protocalcic / calcic gate and the BS \>= 50% requirement.

Note: the v0.2 `chernozem()` diagnostic remains available as a less-strict variant; `chernozem_strict()` is what the v0.3.4 key.yaml uses for the CH RSG.

`claric_material` *Claric material (WRB 2022 Ch 3.3.4): light-coloured fine earth with Munsell criteria.*

Description

Claric material (WRB 2022 Ch 3.3.4): light-coloured fine earth with Munsell criteria.

Usage

```
claric_material(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`ClassificationResult` *ClassificationResult: structured outcome of running a key*

Description

ClassificationResult: structured outcome of running a key

ClassificationResult: structured outcome of running a key

Details

Returned by `classify_wrb2022` (and the future `classify_sibcs`). Carries the full decision trace — which RSGs were tested, which passed, which failed, which were indeterminate because of missing data — plus the assigned class, qualifiers, ambiguities (RSGs that nearly satisfied), missing data that would refine the result, the provenance-aware evidence grade, and any biogeographical or prior-based warnings.

Public fields

`system` Character. `"WRB 2022"` or `"SiBCS 5"`.

`name` Character. Full classification name with qualifiers (e.g. `"Rhodic Ferralsol (Clayic, Humic, Dystric)"`).

`rsg_or_order` Character. Bare RSG (WRB) or order (SiBCS), e.g. `"Ferralsols"`.

`qualifiers` List. Principal and supplementary qualifiers in canonical order.

`trace` List. One element per RSG tested (in key order), each with `code`, `name`, `passed`, `evidence`, `missing`.

`ambiguities` List. RSGs that came close to passing — useful hints for follow-up measurements.

`missing_data` Character vector. Attributes whose measurement would refine or resolve the result.

`evidence_grade` Character. `"A"`, `"B"`, `"C"`, `"D"`, or `NA_character_`.

`prior_check` List or NULL. Result of the spatial-prior sanity check (consistent / inconsistent / not run).

`warnings` Character vector. Free-form warnings.

Methods

Public methods:

- `ClassificationResult$new()`
- `ClassificationResult$print()`
- `ClassificationResult$summary()`
- `ClassificationResult$report()`
- `ClassificationResult$clone()`

Method `new()`**:** Build a ClassificationResult.

Usage:

```
ClassificationResult$new(
  system,
  name,
  rsg_or_order = NA_character_,
  qualifiers = list(),
  trace = list(),
  ambiguities = list(),
  missing_data = character(0),
  evidence_grade = NA_character_,
  prior_check = NULL,
  warnings = character(0)
)
```

Arguments:

`system` System name.

`name` Classification name.

`rsg_or_order` RSG (WRB) or order (SiBCS).

`qualifiers` List of qualifier names.

`trace` List of per-RSG test entries.

`ambiguities` List of close-call RSGs.

`missing_data` Character vector.

`evidence_grade` Single character A/B/C/D or NA.

`prior_check` List or NULL.

`warnings` Character vector.

Method `print()`**:** Pretty-print the result with key trace, ambiguities, and warnings.

Usage:

```
ClassificationResult$print(...)
```

Arguments:

... Ignored (S3 print signature compatibility).

Method `summary()`**:** Compact summary list.

Usage:

```
ClassificationResult$summary(...)
```

Arguments:

... Ignored (S3 summary signature compatibility).

Method `report()`**:** Render this classification as a self-contained report (delegates to the package-level `report` generic). HTML output is dependency-free; PDF requires `rmarkdown` and a working LaTeX engine.

Usage:

```
ClassificationResult$report(
  file,
  format = c("auto", "html", "pdf"),
  pedon = NULL,
  ...
)
```

Arguments:

`file` Output path. Format is inferred from the extension.

`format` One of "html" or "pdf" (defaults to "auto", which infers from the extension).

`pedon` Optional `PedonRecord` whose horizons / provenance are added to the report.

... Forwarded to `report_html` or `report_pdf`.

Method `clone()`**:** The objects of this class are cloneable with this method.

Usage:

```
ClassificationResult$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

`classification_robustness` *Robustness of classification under input perturbation*

Description

For a given `PedonRecord`, perturb a chosen list of horizon attributes by a configured fractional amount, re-classify under the requested system, and report how often the classification `$rsg_or_order` (or full `$name`) matches the unperturbed baseline.

Usage

```
classification_robustness(
  pedon,
  system = c("wrb2022", "sibcs", "usda"),
  level = c("order", "name"),
  n = 50L,
  perturbations = NULL,
  seed = 42L
)
```

Arguments

pedon	A PedonRecord.
system	One of "wrb2022", "sibcs", "usda".
level	Either "order" (compare $rsg_or_order) or "name" (compare full classification name).
n	Number of Monte-Carlo perturbed runs (default 50).
perturbations	Named list. Each name is a horizon column; each element is a function taking the original value and returning a perturbed value. NA-tolerant.
seed	Integer applied through with_seed so the Monte-Carlo draws are reproducible *without* mutating the caller's global RNG state. Pass NULL to leave the RNG stream untouched. Default 42L preserves the bit-for-bit-identical output earlier soilKey releases produced (CRAN policy: never call set.seed() on the caller's RNG).

Details

Default perturbation panel:

- clay_pct: ±5
- sand_pct: ±5
- silt_pct: ±5
- ph_h2o: ±0.2 absolute
- oc_pct: ±10

Value

A list with elements baseline (the unperturbed classification name), n (number of MC runs), robustness (fraction of perturbed runs matching baseline), flipped_to (table of alternative classifications when the perturbation flipped the result).

Examples

```
p <- make_ferralsol_canonical()
classification_robustness(p, system = "wrb2022", n = 50)
#> $baseline    : "Ferralsols"
#> $robustness  : 0.96  (48 / 50 perturbed runs landed on Ferralsols)
```

```
#> $flipped_to  : table(c("Cambisols" = 1, "Acrisols" = 1))
```

`classify_all` *Classify a pedon across all three taxonomic systems*

Description

Convenience wrapper that runs `classify_wrb2022`, `classify_sibcs`, and `classify_usda` on the same `PedonRecord` and returns a single named list with one entry per system (plus a `summary` table that's handy for reports).

Usage

```
classify_all(
  pedon,
  systems = "all",
  on_missing = c("warn", "silent", "error"),
  include_familia = TRUE,
  ...
)
```

Arguments

`pedon`	A `PedonRecord`.
`systems`	Character vector. Any subset of `c("wrb2022","sibcs", "usda")`, or the literal `"all"` (default) to run every system.
`on_missing`	One of `"warn"` (default), `"silent"`, `"error"`. Forwarded verbatim to each classifier.
`include_familia`	Forwarded to `classify_sibcs` (default `TRUE`). Has no effect on the other systems.
`...`	Additional named arguments are silently ignored.

Details

Each classifier still produces its own `ClassificationResult` with the full key trace and evidence grade – nothing is collapsed or homogenised. The wrapper exists for ergonomics, not abstraction.

Value

A named list with elements:

- `wrb` – `ClassificationResult` from `classify_wrb2022()` (or `NULL` if the system was skipped or errored).
- `sibcs` – as above, from `classify_sibcs()`.
- `usda` – as above, from `classify_usda()`.
- `summary` – a 1-row `data.frame` with one column per system, holding the resulting `$name` (or `NA` when the system was skipped / errored). Useful for tabulating many pedons in one shot.

Selecting a subset of systems

Pass `systems = c("wrb2022", "sibcs")` (or any other subset) to skip systems you don't need. Default `systems = "all"` runs all three.

Errors and partial results

If a single classifier raises an error, the corresponding slot of the returned list is set to `NULL` and a one-line warning is emitted (so you can rerun the offender on its own to see the full traceback). The other classifiers still run and their results are returned. This matches the spirit of `on_missing = "warn"` on the individual classifiers.

Side effects

None. The classifiers do not mutate `pedon`; the wrapper does not attach any side-channel state.

See Also

`classify_wrb2022`, `classify_sibcs`, `classify_usda`.

Examples

```
pr <- make_ferralsol_canonical()
all_three <- classify_all(pr)
all_three$summary

# WRB + USDA only (skip SiBCS):
classify_all(pr, systems = c("wrb2022", "usda"))$summary
```

---

classify_by_spectral_neighbours

Classify a soil by spectral similarity to OSSL reference profiles

---

Description

Given a Vis-NIR (or MIR) spectrum and an OSSL reference library enriched with WRB / SiBCS / USDA labels, returns the K most spectrally similar profiles plus a probabilistic class prediction aggregated from their labels.

Usage

```
classify_by_spectral_neighbours(
  spectrum,
  ossl_library,
  system = c("wrb2022", "sibcs", "usda"),
  k = 25L,
  preprocess = "snv+sg1",
  region = NULL,
```

```
  verbose = TRUE
)
```

Arguments

spectrum	Numeric vector or 1-row matrix (the query spectrum). Must align (after preprocessing) with the column space of `ossl_library$Xr`.
ossl_library	A list with `Xr` (numeric matrix, rows = OSSL training profiles, cols = wavelengths) and `Yr` (data frame keyed by property; *must include* a column named `wrb_rsg` and / or `sibcs_ordem` / `usda_order` for the labels to aggregate over). `ossl_library` may also carry `lat` and `lon` columns in `Yr` for the regional filter.
system	One of `"wrb2022"` (default), `"sibcs"`, `"usda"`. Controls which label column of `Yr` is aggregated.
k	Number of nearest neighbours (default 25).
preprocess	Pre-processing pipeline; passed to `preprocess_spectra`. Default `"snv+sg1"`.
region	Optional `list(lat, lon, radius_km)` for a regional filter on `ossl_library$Yr$lat` / `lon`.
verbose	Emit a `cli` summary.

Details

This is the **spectral analogy** classifier. It does not replace the deterministic key in `classify_wrb2022` / `classify_sibcs` / `classify_usda`; instead it provides a high-prior "expected class" before the user has lab data, reducing the search space when collecting confirming attributes.

Value

A list with three elements:

`distribution` A `data.table` with columns `class`, `n_neighbours`, `probability` (= `n_neighbours` / `k`), sorted by probability.

`neighbours` A `data.table` with one row per neighbour (top K), columns `rank`, `distance`, `class`, plus any other columns present in `ossl_library$Yr`.

`query` The query metadata (system, k, region filter, n_library_rows, n_filtered).

Distance metric

By default we compute distances on PLS scores (matching the resemble / OSSL recipe), with PLS components fit on the OSSL reference Yr matrix. When `resemble` is unavailable, we fall back to PCA scores from `stats::prcomp` on the preprocessed Xr – a defensible-but-simpler heuristic.

Region filter

Optional `lat` / `lon` / `radius_km` arguments filter the OSSL library to profiles within `radius_km` (great-circle) of the query location before computing distances. This implements the "biome-aware" use case the architecture document calls for: a Cerrado profile shouldn't have its class inferred from spectral neighbours in the Boreal taiga.

See Also

predict_ossl_mbl (predicts attributes), classify_wrb2022 (the deterministic key).

Examples

```
# Toy run against the bundled demo library (synthetic):
data(ossl_demo_sa)
# Inject a fake label column for the demo (real OSSL has it):
ossl_demo_sa$Yr$wrb_rsg <- sample(c("FR", "AC", "LX", "AL"),
                                   nrow(ossl_demo_sa$Yr),
                                   replace = TRUE)
query <- ossl_demo_sa$Xr[1, ]
res <- classify_by_spectral_neighbours(query, ossl_demo_sa,
                                       k = 10)
res$distribution    # ranked classes
res$neighbours      # the 10 most similar profiles
```

`classify_from_documents`

Build a fully-classified 'PedonRecord' from documents in one call

---

Description

Highest-level entry point of the soilKey VLM pipeline. Given a soil-description PDF and / or a profile-wall photograph, this function:

Usage

```
classify_from_documents(
  pdf = NULL,
  image = NULL,
  fieldsheet = NULL,
  pedon = NULL,
  provider = "auto",
  model = NULL,
  systems = c("wrb", "sibcs", "usda"),
  report = NULL,
  overwrite = FALSE,
  verbose = TRUE
)
```

Arguments

pdf	Optional path to a soil-description PDF.
image	Optional path to a profile-wall image (JPG / PNG); if supplied, Munsell extraction is attempted with the configured provider.

fieldsheet	Optional path to a site-metadata field sheet (image or PDF).
pedon	Optional existing PedonRecord; when supplied, the function fills only the fields VLM extraction can fill (subject to the provenance-authority order).
provider	Either a provider name passed to vlm_provider (default "ollama") OR a pre-built ellmer chat object (when you want full control over system_prompt, api_key, ...).
model	Optional model identifier; passed through to vlm_provider() when provider is a string. Defaults to the per-provider default from default_model.
systems	Character vector listing which classification systems to run; subset of c("wrb", "sibcs", "usda"). Default: all three.
report	Optional output path for a self-contained report (.html or .pdf). When supplied, report is called on the classification results + pedon. Default NULL (no report file).
overwrite	When merging extracted values into an existing pedon, allow VLM-extracted attributes to clobber already-recorded ones. Default FALSE – the provenance authority order (measured > extracted_vlm) is enforced by PedonRecord$add_measurement().
verbose	Emit cli progress messages. Default TRUE.

Details

1. Constructs a vision-language provider chat object via vlm_provider (defaults to local Ollama with Gemma 4 edge for institutional independence and data sovereignty).
2. Extracts horizons from pdf via extract_horizons_from_pdf, Munsell colours from image via extract_munsell_from_photo, and site metadata from fieldsheet via extract_site_from_fieldsheet. Every extracted attribute is stamped source = "extracted_vlm" in the PedonRecord's provenance log.
3. Runs the three deterministic keys (classify_wrb2022, classify_sibcs, classify_usda). The VLM never classifies – the package's architectural invariant is preserved.
4. Optionally renders a one-pager HTML / PDF report via report.

At least one of pdf, image or fieldsheet must be supplied; you can also pass an existing partially-filled PedonRecord via pedon and let this function fill the gaps.

Value

A list with elements:

pedon The (mutated) PedonRecord.

classifications Named list with up to three ClassificationResult objects keyed by wrb, sibcs, usda.

report Path to the rendered report file (if report = ... was supplied), else NULL.

provider The chat-provider object actually used (useful for downstream debugging or cost accounting).

Why local-first by default

The default provider = "ollama" runs the entire VLM pipeline on the user's machine via Gemma 4 (edge variant, ~3 GB, multimodal text+image). No part of the soil description, photograph or field sheet ever leaves the local network. This is the recommended configuration for governmental surveys, indigenous land studies, and unpublished research data; it also makes the pipeline reproducible without an internet connection. Cloud providers ("anthropic", "openai", "google") remain one argument away when they are the right call.

Architectural invariants preserved

- The VLM never classifies. Every extracted value carries source = "extracted_vlm"; the deterministic keys consume the resulting PedonRecord unaware of how each value was obtained.
- Provenance is preserved end-to-end. The evidence_grade on each ClassificationResult reflects whether decisive attributes came from measured, predicted_spectra, extracted_vlm, inferred_prior, or user_assumed – so a caller always knows how robust the classification is.
- Authority order is enforced. A pre-existing measured value is never silently overwritten by a later extracted_vlm value (unless overwrite = TRUE).

See Also

vlm_provider, extract_horizons_from_pdf, classify_wrb2022, report.

Examples

```
# Requires user-provided PDF/image files and a VLM provider; the
# block guards against missing inputs so it no-ops on CRAN.
pdf_path <- "perfil_042_descricao.pdf"
if (file.exists(pdf_path) && interactive()) {
  # The simplest possible end-to-end call -- local Gemma 4 edge.
  res <- classify_from_documents(
    pdf      = pdf_path,
    image    = "perfil_042_parede.jpg",
    report   = file.path(tempdir(), "perfil_042.html")
  )
  res$classifications$wrb$name

  # Cloud provider for a one-shot, production run
  res <- classify_from_documents(
    pdf      = pdf_path,
    provider = "anthropic"
  )

  # Different Gemma 4 size on Ollama
  res <- classify_from_documents(
    pdf      = pdf_path,
    provider = "ollama",
    model    = "gemma4:31b"
```

```
  )
}
```

`classify_sibcs` *Classifica um pedon segundo o SiBCS 5a edicao (1o + 2o + 3o + 4o niveis)*

Description

v0.7 ligou as 13 ordens; v0.7.1 desce ao 2o nivel (subordens) via `run_sibcs_subordem`; v0.7.3 desce ao 3o nivel (Grandes Grupos) via `run_sibcs_grande_grupo` para as ordens progressivamente wiradas em `inst/rules/sibcs5/grandes-grupos/<ordem>.yaml` (Cap 14 Organossolos primeiro). Quando a subordem ainda nao tem bloco de Grandes Grupos, ou quando nenhum Grande Grupo passa (e nao ha catch-all default), a classificacao para no 2o nivel.

Usage

```
classify_sibcs(
  pedon,
  rules = NULL,
  on_missing = c("warn", "silent", "error"),
  include_familia = FALSE
)
```

Arguments

`pedon` A `PedonRecord`.

`rules` Conjunto de regras pre-carregado.

`on_missing` Um de `"warn"` (default), `"silent"`, `"error"`.

`include_familia` Quando `TRUE` (default `FALSE`), adiciona o 5o nivel categorico (Familia) via `classify_sibcs_familia`. O label textual da Familia aparece em `$trace$familia_label`, e a lista de `FamilyAttributes` em `$trace$familia`.

Value

Um `ClassificationResult` cujo `name` eh o nome completo da classe atribuida no nivel mais profundo (Grande Grupo > Subordem > Ordem) e `rsg_or_order` eh o nome da ordem (e.g. "Organossolos"). Os codigos de cada nivel e o trace ficam em `$trace`.

`classify_sibcs_familia`

Classifica um perfil no 5o nivel categorico do SiBCS (Familia)

Description

Aplica as dimensoes pertinentes a ordem do solo e devolve uma lista nomeada de `FamilyAttribute`. O label textual da Familia eh formado adicionando-se cada `value` nao-nulo apos a designacao do 4o nivel, separados por virgulas (Cap 18, p 281).

Usage

```
classify_sibcs_familia(
  pedon,
  ordem_code = NULL,
  sg_code = NULL,
  max_depth_cm = 200
)
```

Arguments

`pedon`	A `PedonRecord`.
`ordem_code`	Codigo da ordem (1 letra: "P", "L", ...). Se `NULL`, sera derivado de `sg_code`.
`sg_code`	Codigo do subgrupo do 4o nivel (e.g. "PVdAr"). Opcional; usado para ajustes especificos por SG (e.g. forcar subgrupamento textural em arenicos/espessarenicos).
`max_depth_cm`	Profundidade da secao de controle (default 200 cm).

Details

Esta funcao NAO eh uma chave determinista: cada perfil recebe SIMULTANEAMENTE todos os adjetivos pertinentes (multi-rotulo).

Value

Lista nomeada de `FamilyAttribute`.

Status v0.7.14.A

Implementadas 5 dimensoes – grupamento textural, subgrupamento textural, distribuicao de cascalhos, constituicao esqueletica, tipo de horizonte superficial. Outras dimensoes (prefixos epi/meso/endo, saturacao de bases, alico, mineralogia, atividade da argila, oxidos de ferro, andico, especificos de Organossolos) adicionadas em sub-commits subsequentes.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, pp 281-288.

classify_usda *Classify a pedon under USDA Soil Taxonomy (13th edition)*

Description

Walks the canonical 4-level USDA key (Order -> Suborder -> Great Group -> Subgroup) using YAML rule files at:

- `inst/rules/usda/key.yaml`: Order key (12 entries)
- `inst/rules/usda/suborders/<order>.yaml`
- `inst/rules/usda/great-groups/<order>.yaml`
- `inst/rules/usda/subgroups/<order>.yaml`

Usage

```
classify_usda(pedon, rules = NULL, on_missing = c("warn", "silent", "error"))
```

Arguments

`pedon`	A `PedonRecord`.
`rules`	Optional pre-loaded rule set.
`on_missing`	One of `"warn"` (default), `"silent"`, `"error"`.

Details

Stops at the deepest level for which a YAML rule file is available (e.g. v0.8.x: Gelisols full Path C; other 11 Orders at Order level only).

Value

A `ClassificationResult` with deepest-level taxon name. Each level's trace is in `$trace`.

References

Soil Survey Staff (2022). Keys to Soil Taxonomy, 13th edition. USDA Natural Resources Conservation Service.

`classify_via_smartsolos_api` *Classify a PedonRecord via Embrapa's SmartSolosExpert REST API*

Description

Sends a soilKey `PedonRecord` to the SmartSolosExpert REST endpoint maintained by Embrapa (Glauber Vaz's PROLOG-based implementation of the SiBCS classifier) and returns the resulting four-level classification (Ordem / Subordem / Grande Grupo / Subgrupo) wrapped in a soilKey `ClassificationResult`.

Usage

```
classify_via_smartsolos_api(
  pedon,
  api_key = Sys.getenv("AGROAPI_TOKEN"),
  endpoint = c("classification", "verification"),
  drenagem = NULL,
  reference_sibcs = NULL,
  base_url = "https://api.cnptia.embrapa.br/smartsolos/expert/v1",
  timeout_seconds = 30,
  post_fn = NULL,
  verbose = TRUE
)
```

Arguments

`pedon`	A `PedonRecord`.
`api_key`	Bearer token. Defaults to `Sys.getenv("AGROAPI_TOKEN")`. Required unless `post_fn` is supplied (test injection).
`endpoint`	One of `"classification"` (default; classify only) or `"verification"` (classify + compare against user-supplied `reference_sibcs`).
`drenagem`	Optional drainage class. Integer 1..8 or Portuguese string (`"bem drenado"` etc.).
`reference_sibcs`	Optional named list (`ordem`, `subordem`, `gde_grupo`, `subgrupo`) used by the `"verification"` endpoint as the user's reference.
`base_url`	Override base URL. Default `"https://api.cnptia.embrapa.br/smartsolos/expert/v1"`.
`timeout_seconds`	HTTP timeout (default 30).
`post_fn`	Internal: function with signature `function(payload) -> response_list` for unit tests. When supplied, the network is bypassed.
`verbose`	If `TRUE` (default), emits a one-line summary.

Details

This is an **external classifier** – the package does not host or replicate the PROLOG rules. The function exists so soilKey users can cross-validate the local classifier against an authoritative Embrapa-hosted reference. Use the `"verification"` endpoint to compare against your own user-supplied reference classification (the API returns a per-level match `summary` with counters `L0..L4`).

Authentication: register a free AgroAPI account at `https://www.agroapi.cnptia.embrapa.br/portal/`, subscribe to the SmartSolosExpert API and generate an access token. Pass it via the `AGROAPI_TOKEN` environment variable or the `api_key` argument.

Value

A `ClassificationResult` with `system = "SiBCS 5a edicao (SmartSolosExpert API)"` and the four taxonomic levels in `rsg_or_order` (Ordem) and `qualifiers` (Subordem / GdeGrupo / Subgrupo). Verification-mode responses additionally carry `trace$smartsolos_summary` (the per-level match counters `L0..L4`).

References

Vaz, G. J., Silva Neto, L. de F. da, & Barbedo, J. G. A. (2025). SmartSolos Expert: an expert system for Brazilian soil classification. *Smart Agricultural Technology*, 10, 100735. doi:10.1016/j.atech.2024.100735.

Vaz, G. J., Silva Neto, L. de F. da, Lima, R. N., & Oliveira, S. R. de M. (2019). Uma API para a classificacao de solos do Brasil. In *Anais do 12 Congresso Brasileiro de Agroinformatica* (SBIAGRO 2019), pp. 63-72. Ponta Grossa.

Vaz, G. J., Silva Jr, A. F., & Silva Neto, L. de F. da (2023). Brazilian soil data for taxonomic classification. *Redape*, V1. doi:10.48432/PYKKA7.

See Also

`classify_sibcs` for the local PROLOG-free classifier; `compare_smartsolos` for a side-by-side comparison helper; `benchmark_redape` for the gold-standard curated dataset published by the same authors.

Examples

```
# Needs a SmartSolos Expert API token (set AGROAPI_TOKEN) and
# network access; the example no-ops on CRAN.
if (nzchar(Sys.getenv("AGROAPI_TOKEN")) &&
      requireNamespace("httr", quietly = TRUE)) {
  res <- try(classify_via_smartsolos_api(make_argissolo_canonical()),
             silent = TRUE)
  if (!inherits(res, "try-error")) {
    res$rsg_or_order      # "ARGISSOLO"
    res$qualifiers
  }
}
```

`classify_with_engine_heuristic`
Classify a pedon with the engine chosen by 'pick_engine()'

Description

Convenience wrapper that routes `classify_wrb2022` / `classify_sibcs` / `classify_usda` through whichever engine the heuristic recommends for the specific pedon.

Usage

```
classify_with_engine_heuristic(
  pedon,
  system = c("wrb2022", "sibcs", "usda"),
  min_score = 3L,
  ...
)
```

Arguments

`pedon`	A `PedonRecord`.
`system`	One of `"wrb2022"`, `"sibcs"`, `"usda"`.
`min_score`	Forwarded to `pick_engine`.
`...`	Forwarded to the underlying classifier.

Value

The result of the chosen classifier (a `ClassificationResult`). The chosen engine is captured in `$trace$engine_used`.

`classify_wrb2022` *Classify a pedon under WRB 2022*

Description

High-level classification entry point. Pre-computes the implemented diagnostic horizons (argic, ferralic, mollic) for transparent reporting, runs the key, and assembles a `ClassificationResult` with the trace, ambiguities, missing-data hints, evidence grade, and (in future) prior sanity check.

Usage

```
classify_wrb2022(
  pedon,
  prior = NULL,
  prior_threshold = 0.01,
  on_missing = c("warn", "silent", "error"),
  rules = NULL
)
```

Arguments

`pedon`	A `PedonRecord`.
`prior`	Optional spatial prior – a `data.table` with columns `rsg_code` and `probability`, typically the return value of `spatial_prior`. If supplied, the result records a `prior_check` entry from `prior_consistency_check`; an inconsistent prior also emits a warning. The deterministic key is NEVER overridden by the prior.
`prior_threshold`	Probability below which the prior triggers an "inconsistent" warning (default 0.01).
`on_missing`	One of `"warn"` (default), `"silent"`, `"error"`. Behaviour when the trace reports missing attributes.
`rules`	Optional pre-loaded rule set.

Value

A `ClassificationResult`.

`clear_kst13_cache` *Clear the in-memory KST13 cache*

Description

Useful when the vendored JSON files are updated mid-session. Frees ~3.1 MB.

Usage

```
clear_kst13_cache()
```

`clear_ossl_cache` *Clear the soilKey OSSL cache*

Description

Removes the per-region cache files written by `download_ossl_subset`. Useful when a stale cache is suspected or when disk space is tight.

Usage

```
clear_ossl_cache(region = NULL, cache_dir = NULL, verbose = TRUE)
```

Arguments

`region`	Optional character vector of regions to clear; the default `NULL` clears every cached file under 'tools::R_user_dir("soilKey", "cache")'.
`cache_dir`	Cache directory (defaults to the soilKey user-cache dir).
`verbose`	If `TRUE`, prints which files were removed.

Value

Invisibly, the character vector of files that were removed.

`combine_priors` *Combine multiple spatial priors via weighted geometric mean*

Description

Given a list of priors (each a data.table with `rsg_code,probability`), pools them into a single distribution using a weighted geometric mean and renormalises to sum to 1.

Usage

```
combine_priors(priors, weights = NULL, epsilon = 1e-06)
```

Arguments

`priors`	A list of `data.tables` with columns `rsg_code` and `probability`.
`weights`	Optional non-negative numeric vector of length `length(priors)`. Defaults to equal weights. Will be renormalised to sum to 1.
`epsilon`	Smoothing floor for classes missing from a prior (default 1e-6). Must be > 0 – otherwise any class missing from a single prior is suppressed entirely.

Details

Geometric pooling has two desirable properties for soil-class priors:

1. externally Bayesian (the pooled posterior under any common likelihood matches what one would get by individual updates), and
2. zero-preserving: a class assigned probability 0 by any prior is suppressed in the pooled distribution. To avoid that, classes absent from a given prior are imputed with the smoothing constant `epsilon`.

Value

A `data.table` with columns `rsg_code`, `probability`, sorted by descending probability.

`compare_engines` *Side-by-side comparison of soilKey vs aqp diagnostic engines*

Description

Runs the soilKey hand-coded diagnostic and the aqp wrapper on the same pedon, returns both results plus an agreement flag. Useful for A/B benchmarks and for choosing which engine to use per dataset.

Usage

```
compare_engines(pedon, diagnostic = c("argic", "cambic"))
```

Arguments

`pedon`	A `PedonRecord`.
`diagnostic`	One of `"argic"` or `"cambic"`.

Value

A list with `soilkey`, `aqp`, `agree`.

compare_smartsolos — *Cross-validate the local SiBCS classifier against the SmartSolosExpert API*

Description

Runs both classify_sibcs (local) and classify_via_smartsolos_api (remote PROLOG via Embrapa AgroAPI) on the same PedonRecord and tabulates agreement at each of the four SiBCS categorical levels.

Usage

```
compare_smartsolos(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Forwarded to classify_via_smartsolos_api.

Value

A list with `local` and `remote` `ClassificationResults` plus a one-row `agreement` data.frame with columns `ordem`, `subordem`, `gde_grupo`, `subgrupo`, `n_match`.

Examples

```
if (nzchar(Sys.getenv("AGROAPI_TOKEN")) &&
      requireNamespace("httr", quietly = TRUE)) {
  cmp <- try(compare_smartsolos(make_argissolo_canonical()),
             silent = TRUE)
  if (!inherits(cmp, "try-error")) cmp$agreement
}
```

compute_ki — *Ki (silica:alumina molar) – SiBCS Cap 1, p 32*

Description

Calcula o indice molar Ki = SiO2 / Al2O3 a partir de teores percentuais por ataque sulfurico-NaOH (Embrapa Manual de Metodos). Massas molares: 60.08 (SiO2), 101.96 (Al2O3):

Usage

```
compute_ki(sio2_pct, al2o3_pct)
```

Arguments

sio2_pct	Teor de SiO2 por ataque sulfurico (%).
al2o3_pct	Teor de Al2O3 por ataque sulfurico (%).

Details

Ki (molar) = (% SiO2 / 60.08) / (% Al2O3 / 101.96) $\approx$ 1.6973 $\times$ (% SiO2 / % Al2O3)

Value

Ki molar (numeric); NA se algum input for NA ou Al2O3 ≤ 0.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 32; Embrapa Manual de Metodos de Analise de Solo (3a ed., 2017).

`compute_kr` *Kr (silica:sesquioxidos molar) – SiBCS Cap 1, p 32*

Description

Calcula o indice molar Kr = SiO2 / (Al2O3 + Fe2O3) usando massas molares 60.08 (SiO2), 101.96 (Al2O3) e 159.69 (Fe2O3):

Usage

```
compute_kr(sio2_pct, al2o3_pct, fe2o3_pct)
```

Arguments

sio2_pct	Teor de SiO2 por ataque sulfurico (%).
al2o3_pct	Teor de Al2O3 por ataque sulfurico (%).
fe2o3_pct	Teor de Fe2O3 por ataque sulfurico (%).

Details

Kr (molar) = (% SiO2 / 60.08) / (% Al2O3 / 101.96 + % Fe2O3 / 159.69)

Value

Kr molar (numeric); NA se algum input for NA ou denominador ≤ 0.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 32.

`contato_litico` *Contato litico (SiBCS Cap 1, p 40): rocha continua dura. Reuso de* `continuous_rock` *via designacao R / Cr.*

Description

Contato litico (SiBCS Cap 1, p 40): rocha continua dura. Reuso de `continuous_rock` via designacao R / Cr.

Usage

```
contato_litico(pedon, max_depth_cm = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`max_depth_cm`	Profundidade maxima do contato (default `NULL`). SiBCS Cap 14 Subgrupos liticos de Folicos usam `max_depth_cm = 50`.

`contato_litico_fragmentario` *Contato litico fragmentario (SiBCS Cap 1, p 40): rocha fragmentada.*

Description

Contato litico fragmentario (SiBCS Cap 1, p 40): rocha fragmentada.

Usage

```
contato_litico_fragmentario(pedon, max_depth_cm = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`max_depth_cm`	Profundidade maxima do contato (default `NULL`). SiBCS Cap 14 Subgrupos fragmentarios de Folicos usam `max_depth_cm = 50`.

continuous_rock — *Continuous rock (WRB 2022 Ch 3.2.5)*

Description

Consolidated material below the soil. v0.3.3: detects via designation `R` or `Cr` on the lowermost (or any) layer.

Usage

```
continuous_rock(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

cryic_conditions — *Cryic conditions (WRB 2022)*

Description

Tests whether continuous frozen / permafrost material occurs within the upper `max_top_cm`. Two alternative paths qualify per WRB 2022:

1. **Permafrost temperature**: a layer at top_cm <= `max_top_cm` (default 100) with `permafrost_temp_C` <= `max_temp_C` (default 0 C).
2. **Designation pattern**: a layer at top_cm <= `max_top_cm` with designation containing suffix `"f"` (frozen) or matching `"^Cf"` / `"perma"`. Used as a fallback when the temperature field is not in the pedon (typical of legacy survey data).

Either path qualifies. Diagnostic of Cryosols.

Usage

```
cryic_conditions(pedon, max_top_cm = 100, max_temp_C = 0)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Maximum top depth (cm) (default 100).
`max_temp_C`	Maximum mean annual permafrost-zone temperature (deg C) for the temperature path (default 0).

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Cryosols.

`cryoturbation_usda` *Cryoturbation (USDA Soil Taxonomy, 13th edition)*

Description

"Cryoturbation (frost churning) is the mixing of the soil matrix within the pedon that results in irregular or broken horizons, involutions, accumulation of organic matter on the permafrost table, oriented rock fragments, and silt caps on rock fragments." – KST 13ed, Ch 3, p 43.

Usage

```
cryoturbation_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Details

Diagnostic for the Turbels suborder of Gelisols.

Implementation (v0.8.x): Uses heuristics from horizon designations and morphology data:

- Designation contains 'jj' (cryoturbation symbol) per KST notation;
- OR boundary_topography in {"irregular", "broken", "involuted"};
- OR coarse_fragments_pct varying non-monotonically with depth (proxy for "oriented rock fragments");
- OR designation contains 'f' (frozen) AND irregular boundary_distinctness.

Refinement to incorporate explicit `cryoturbation_evidence` column is deferred to v0.9.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, p 43.

cumulic_subgroup_usda *Cumulic Subgroup helper (Mollorthels / Umbrorthels)*

Description

Pass when:

- Mollic or umbric epipedon >= 40 cm thick with texture finer than loamy fine sand; AND
- Slope < 25 percent.

Usage

```
cumulic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Slope is taken from `site$slope_pct` when available; if NA, assumed to satisfy (TRUE).

Value

A `DiagnosticResult`.

densiaquept_qualifying_usda *Densiaquept qualifying (densic contact within 100 cm)*

Description

Densiaquept qualifying (densic contact within 100 cm)

Usage

```
densiaquept_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`DiagnosticResult` *DiagnosticResult: structured outcome of a diagnostic test*

Description

DiagnosticResult: structured outcome of a diagnostic test

DiagnosticResult: structured outcome of a diagnostic test

Details

Returned by every WRB or SiBCS diagnostic function (e.g. `argic`, `ferralic`, `mollic`). A DiagnosticResult never reduces to a bare TRUE/FALSE — it always carries (a) which layers satisfied the criteria, (b) the per-sub-test evidence, (c) which attributes would have been required but are missing, and (d) the literature reference for the diagnostic definition.

`passed` is `TRUE`/`FALSE`/`NA`; `NA` means the test could not be evaluated because critical attributes were missing. This three-valued semantics propagates through the rule engine — an indeterminate test does not silently fail.

Public fields

`name` Character. Name of the diagnostic (e.g. `"argic"`).

`passed` Logical. `TRUE`, `FALSE`, or `NA`.

`layers` Integer vector. Indices of horizons that satisfy the diagnostic.

`evidence` Named list. Sub-test results, each itself a list with at least `passed`, `layers`, and `missing`.

`missing` Character vector. Attribute names that would have been needed but were NA.

`reference` Character. Literature citation for this diagnostic.

`notes` Character. Free-form notes (interpretation choices, edge cases hit).

Methods

Public methods:

- `DiagnosticResult$new()`
- `DiagnosticResult$print()`
- `DiagnosticResult$as_list()`
- `DiagnosticResult$clone()`

Method `new()`**:** Build a DiagnosticResult.

Usage:

```
DiagnosticResult$new(
  name,
  passed = NA,
  layers = integer(0),
  evidence = list(),
  missing = character(0),
```

```
  reference = NA_character_,
  notes = NA_character_
)
```

Arguments:

`name` Diagnostic name.

`passed` `TRUE/FALSE/NA`.

`layers` Integer vector of horizon indices that satisfied.

`evidence` Named list of sub-test results.

`missing` Character vector of missing attribute names.

`reference` Citation string.

`notes` Free-form notes.

Method `print()`**:** Pretty-print the result with sub-test breakdown.

Usage:

```
DiagnosticResult$print(...)
```

Arguments:

`...` Ignored (S3 print signature compatibility).

Method `as_list()`**:** Return the result as a plain list (for serialization).

Usage:

```
DiagnosticResult$as_list()
```

Method `clone()`**:** The objects of this class are cloneable with this method.

Usage:

```
DiagnosticResult$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

`distrofico` *Solo distrofico (SiBCS Cap 1, p 30)*

Description

Negacao operacional de `eutrofico`: V < 50% no horizonte diagnostico subsuperficial.

Usage

```
distrofico(pedon, max_v = 50)
```

Arguments

`pedon`	A `PedonRecord`.
`max_v`	Numeric threshold or option (see Details).

`dolomitic_material` *Dolomitic material (WRB 2022 Ch 3.3.5): \>= 2% Mg-rich carbonate, CaCO3/MgCO3 < 1.5. v0.3.3: detects via designation pattern* `kdo|do|magn` *as proxy when ratio data missing.*

Description

Dolomitic material (WRB 2022 Ch 3.3.5): \>= 2% Mg-rich carbonate, CaCO3/MgCO3 < 1.5. v0.3.3: detects via designation pattern `kdo|do|magn` as proxy when ratio data missing.

Usage

```
dolomitic_material(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`download_bdsolos` *Download the BDsolos consulta-publica CSV (experimental, requires chromote)*

Description

Drives the Embrapa BDsolos web form via headless Chrome (`chromote`) to produce a CSV of all profiles + all attributes. Marked **experimental**: heavy queries (no UF filter) frequently overload the Embrapa server. Prefer `filter_uf` = batches of one or two states at a time and stitch the resulting CSVs.

Usage

```
download_bdsolos(
  out_path,
  accept_terms = FALSE,
  filter_uf = NULL,
  attributes = "default",
  timeout_seconds = 600,
  chromote_session = NULL,
  verbose = TRUE
)
```

Arguments

- `out_path` File path for the downloaded CSV.
- `accept_terms` Logical. Must be `TRUE` to proceed; the function aborts otherwise. Documents informed consent to the BDsolos terms (personal/academic use, ABNT citation).
- `filter_uf` Optional 2-letter UF code (e.g. `"RJ"`, `"SC"`). Strongly recommended – the full-table query often times out.
- `attributes` Character vector. Which attribute groups to request. Defaults to the full SiBCS-classification-relevant set (Identificacao + Localizacao + Classificacao for Pontos de Amostragem, Identificacao + Morfologicas + Fisicas + Quimicas for Horizontes; Mineralogicas excluded for performance). Pass `"all"` to include Mineralogicas.
- `timeout_seconds` Total timeout for the AJAX query. Default 600 (10 min).
- `chromote_session` Optional pre-built `chromote::ChromoteSession`. Useful to share a session across calls.
- `verbose` If `TRUE` (default), prints progress.

Details

Per the Embrapa terms-of-use, the data is licensed for personal / academic use and publications must cite the source per ABNT. **Set `accept_terms = TRUE` to acknowledge this and let the function click "Concordo" on your behalf.**

Value

File path to the downloaded CSV (invisible).

See Also

`load_bdsolos_csv`, `inspect_bdsolos_csv`.

Examples

```
if (requireNamespace("chromote", quietly = TRUE) && interactive()) {
  out_dir <- file.path(tempdir(), "bdsolos")
  dir.create(out_dir, showWarnings = FALSE, recursive = TRUE)

  # Single UF (fast, recommended)
  download_bdsolos(file.path(out_dir, "RJ.csv"),
                   accept_terms = TRUE,
                   filter_uf    = "RJ")

  # Stitch multiple UFs
  for (uf in c("RJ", "SP", "MG", "ES")) {
    download_bdsolos(file.path(out_dir, paste0(uf, ".csv")),
                     accept_terms = TRUE, filter_uf = uf)
  }
```

```
  # Then load all of them
  csvs <- list.files(out_dir, "\\.csv$", full.names = TRUE)
  all_pedons <- unlist(lapply(csvs, load_bdsolos_csv), recursive = FALSE)
  length(all_pedons)
}
```

---

download_extdata_cache *Download one or more soilKey lazy-fetch caches from GitHub Release*

Description

soilKey ships four large benchmark caches (KSSL, KSSL+NASIS, AfSP, WoSIS stratified) that are too large to embed in the CRAN source tarball. Since v0.9.94 they are pinned to a versioned GitHub Release and downloaded on demand into the user cache directory at `tools::R_user_dir("soilKey", "data")`.

Usage

```
download_extdata_cache(
  which = "all",
  release = .SOILKEY_LAZY_FETCH_RELEASE,
  overwrite = FALSE,
  verbose = TRUE
)
```

Arguments

which	Character vector of cache names to download. `"all"` (default) downloads every lazy-fetch cache. Valid names: `"afsp_sample"`, `"kssl_sample"`, `"kssl_nasis_sample"`, `"wosis_stratified_sample"`.
release	GitHub Release tag to pull from (default `"v0.9.94-data"`). Override only if you maintain a local mirror.
overwrite	If `TRUE`, redownload even if the file is already present in the user cache (default `FALSE`).
verbose	Print progress (default `TRUE`).

Details

On first call to any of `load_kssl_sample()`, `load_kssl_nasis_sample()`, `load_afsp_sample()`, or `load_wosis_stratified_sample()`, soilKey checks for the file in the user cache. If missing, the loader prompts (interactive sessions only) to download. Use `download_extdata_cache()` to eagerly populate the cache without prompting.

Value

Invisibly, a named character vector of local paths to the downloaded files.

Examples

```
# Network-dependent; the example no-ops on CRAN.
if (interactive()) {
  # Download every lazy-fetch cache once, ahead of any benchmark run:
  download_extdata_cache()

  # Or just the WRB AfSP sample:
  download_extdata_cache("afsp_sample")
}
```

---

download_ossl_subset   *Download an OSSL subset and return an 'ossl_library' artefact*

Description

Fetches a region-filtered subset of the Open Soil Spectral Library (Sanderman et al. 2024) and assembles it into the 'list(Xr, Yr, metadata)' shape consumed by `predict_ossl_mbl` and `predict_ossl_plsr_local`. The result is cached under 'tools::R_user_dir("soilKey", "cache")' so subsequent calls in the same session (or future R sessions) skip the network.

Usage

```
download_ossl_subset(
  region = c("global", "south_america", "north_america", "europe", "africa", "asia",
    "oceania"),
  properties = c("clay_pct", "sand_pct", "silt_pct", "cec_cmol", "bs_pct", "ph_h2o",
    "oc_pct", "fe_dcb_pct", "caco3_pct"),
  wavelengths = 350:2500,
  endpoint = NULL,
  cache_dir = NULL,
  force = FALSE,
  verbose = TRUE
)
```

Arguments

`region`	One of `"global"`, `"south_america"`, `"north_america"`, `"europe"`, `"africa"`, `"asia"`, `"oceania"`. Filters the OSSL training rows by their site coordinates' continent.
`properties`	Character vector of OSSL property names to keep in 'Yr' (drops other reference columns to keep the artefact small). Defaults to the WRB-relevant set used by `fill_from_spectra`.

wavelengths	Integer vector of wavelengths (nm) the returned `Xr` matrix will be interpolated to. Defaults to Vis-NIR/SWIR (350-2500 nm at 1-nm resolution, 2151 columns).
endpoint	OSSL HTTP endpoint serving the JSON manifest; overrideable via `options(soilKey.ossl_endpoint = ...)` for testing or for using a private mirror. The default is the public Soil Spectroscopy GG bucket.
cache_dir	Cache directory; defaults to `tools::R_user_dir("soilKey", "cache")`.
force	If `TRUE`, re-fetches even when a cached subset exists.
verbose	If `TRUE`, emits a 'cli' summary of the fetch.

Details

This function intentionally does **not** fall back to the synthetic predictor on network failure – a missing OSSL artefact is a real condition that the caller must handle, and silent fallback would make benchmarks meaningless.

Value

A list with elements `Xr` (numeric matrix, rows = training profiles, columns = wavelengths in nm), `Yr` (data.frame with the requested property columns, rows aligned to `Xr`), and `metadata` (snapshot date, region, n profiles, source URL, and the SHA-256 of the cache file). Pass it as the `ossl_library` argument to `fill_from_spectra` or `predict_ossl_mbl`.

References

Sanderman, J., Savage, K., Dangal, S.R.S., Duran, G., Rivard, C., Cardona, M.T., Sandzhieva, A., Aramian, A. & Safanelli, J.L. (2024). Soil Spectroscopy for Global Good – the Open Soil Spectral Library (OSSL). https://soilspectroscopy.org/.

`download_ossl_subset_with_labels`
Download an OSSL subset and attach WRB / SiBCS / USDA labels

Description

Fetches a region-filtered slice of the Open Soil Spectral Library via `download_ossl_subset` and post-joins WRB Reference Soil Group labels from WoSIS GraphQL by spatial nearest-neighbour. The resulting artefact has the canonical `list(Xr, Yr, metadata)` shape – with extra columns in `Yr`: `wrb_rsg`, `wrb_label_source`, `wrb_label_distance_km`, plus optionally `sibcs_ordem` and `usda_order` when `translate_systems = TRUE`.

Usage

```
download_ossl_subset_with_labels(
  region = c("global", "south_america", "north_america", "europe", "africa", "asia",
    "oceania"),
  max_distance_km = 5,
```

```
  wosis_endpoint = NULL,
  translate_systems = TRUE,
  max_to_label = Inf,
  verbose = TRUE,
  query_fn = NULL,
  ...
)
```

Arguments

- `region` — OSSL region filter; one of "global", "south_america", "north_america", "europe", "africa", "asia", "oceania".
- `max_distance_km` — WoSIS spatial-join tolerance in kilometres (default 5). Profiles whose nearest WRB-labeled WoSIS neighbour is farther than this are left unlabeled.
- `wosis_endpoint` — Override for the WoSIS GraphQL endpoint (default `getOption("soilKey.wosis_graphql")`). The canonical value is "https://graphql.isric.org/wosis/graphql".
- `translate_systems` — If `TRUE` (default), also adds `sibcs_ordem` and `usda_order` columns derived from the WRB label via the Schad (2023) Annex Table 1 / SiBCS 5ª ed. Annex A correspondence. Those translations are 1:N for some classes; we pick the most-common partner and tag rows where the translation is genuinely ambiguous.
- `max_to_label` — Maximum number of profiles to query against WoSIS (default `Inf`). WoSIS throttles aggressive queries; cap this when running interactive demos.
- `verbose` — Emit `cli` progress messages.
- `query_fn` — Optional injection of the per-coordinate WoSIS query function. Default uses `.query_nearest_wosis_wrb`. Tests pass a stub here to exercise the join logic without network.
- `...` — Forwarded to `download_ossl_subset`.

Value

A list with `Xr` (numeric matrix), `Yr` (data frame with the labels attached), and `metadata` (list with the OSSL fetch metadata + the join statistics: number of profiles labeled, average / max distance, WoSIS endpoint, snapshot date).

Why this function exists

OSSL stores Vis-NIR / MIR spectra and lab data but typically lacks WRB Reference Soil Group labels on most profiles (KSSL data is USDA-flavoured; non-US contributions are inconsistent). WoSIS, by contrast, archives ~228 000 profiles with WRB labels but no spectra. This function bridges the two so the user can run `classify_by_spectral_neighbours` on a real-data OSSL library without having to do the spatial join themselves.

Caveats and provenance

WRB labels obtained via spatial join are **weak labels**. The same physical location may have been classified differently across surveys (different WRB editions, different interpretations). Each row carries:

- `wrb_label_source = "wosis_spatial_join"`: label inherited from a WoSIS neighbour within `max_distance_km`.
- `wrb_label_distance_km`: the distance to that neighbour (NA when no neighbour was found within tolerance).
- `wrb_label_source = "ossl_native"`: label was already present in OSSL Yr (rare; preserved verbatim).
- `wrb_label_source = "missing"`: no neighbour within tolerance; the row stays unlabeled and will be skipped downstream.

Treat the labels as priors, not ground truth.

See Also

`download_ossl_subset`, `classify_by_spectral_neighbours`.

Examples

```
# Pulls OSSL + WoSIS over the network; the example no-ops on CRAN.
if (interactive()) {
  lib <- try(download_ossl_subset_with_labels(
    region          = "south_america",
    max_distance_km = 10
  ), silent = TRUE)
  if (!inherits(lib, "try-error")) {
    table(lib$Yr$wrb_rsg, useNA = "always")
    table(lib$Yr$wrb_label_source)
  }
}
```

---

download_redape_dataset

Download the curated Redape GeoTab dataset (Vaz et al 2023)

Description

Enumerates the dataset via the Dataverse API and downloads all JSON profile files (the structured / interoperable format used by the curators) into `dest_dir`. Skips files already present unless `overwrite = TRUE`.

Usage

```
download_redape_dataset(
  dest_dir,
  dataset_doi = .REDAPE_GEOTAB_DOI,
  include_rtf = FALSE,
  overwrite = FALSE,
  verbose = TRUE
)
```

Arguments

`dest_dir`	Destination directory for the JSON files.
`dataset_doi`	DOI of the dataset (default: the Vaz 2023 dataset).
`include_rtf`	If `TRUE`, also download the original RTF profile sheets (default `FALSE`; the JSON files alone are enough for classification).
`overwrite`	If `TRUE`, re-download files that already exist locally.
`verbose`	Print progress (default `TRUE`).

Value

Character vector of paths to the downloaded files.

References

Vaz, G. J., Silva Jr, A. F., & Silva Neto, L. de F. da (2023). Brazilian soil data for taxonomic classification. Redape, V1. doi:10.48432/PYKKA7.

`duric_horizon` *Duric horizon (WRB 2022)*

Description

Tests for >= 10% volume of duripan nodules (Si-cemented) within a horizon at least 10 cm thick. Diagnostic of Durisols.

Usage

```
duric_horizon(pedon, min_thickness = 10, min_duripan_pct = 10)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness (cm; default 10 per WRB 2022).
`min_duripan_pct`	Minimum duripan volume % (default 10 per WRB 2022).

Value

A DiagnosticResult.

v0.3.1: thresholds aligned with WRB 2022 Ch 3.1.7 (10%, 10 cm) – previous v0.3 used 15%/15 cm. Petroduric (cemented continuous duripan) detection still deferred and will be added in v0.4.

References

IUSS Working Group WRB (2022), Chapter 3.1.7 – Duric horizon (p. 41).

---

duric_subgroup_usda *Duric Subgroup helper (USDA Spodosols)*

Description

Pass when a pedogenically cemented horizon (extremely weakly coherent or stronger) is present in 90%+ of the pedon within 100 cm. v0.8 proxy: any horizon with cementation_class >= "weakly".

Usage

```
duric_subgroup_usda(pedon, max_top_cm = 100)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Default 100.

Value

A DiagnosticResult.

---

duripa *Duripa (SiBCS Cap 2, p 74; v0.7)*

Description

Reuso de duric_horizon (WRB Ch 3.1): subsuperficial cimentado por silica, continuo ou em \>= 50% volume.

Usage

```
duripa(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Reserved for future arguments.

duripan_usda *Duripan (USDA, KST 13ed Ch 3, pp 36-37)*

Description

Silica-cemented horizon, very strongly resistant. Detected via `cementation_class == "indurated"` AND `duripan_pct >= 50`.

Usage

```
duripan_usda(pedon, max_top_cm = 100)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Default 100.

Value

A DiagnosticResult.

---

dystric_subgroup_usda *Dystric Subgroup helper (Vertisols Dystr*) Pass when BS (NH4OAc) < 50% in some part of the upper 100 cm.*

Description

Dystric Subgroup helper (Vertisols Dystr*) Pass when BS (NH4OAc) < 50% in some part of the upper 100 cm.

Usage

```
dystric_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

entic_subgroup_usda — *Entic Subgroup helper (Spodosols)*

Description

Pass when the spodic horizon is "weakly developed":

- Less than 1.2% organic carbon in the upper 10 cm of spodic; OR
- Spodic horizon < 10 cm thick.

Usage

```
entic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

entisol_usda — *Entisols (USDA Cap 8): catch-all for soils that don't match any other Order. Always passes.*

Description

Entisols (USDA Cap 8): catch-all for soils that don't match any other Order. Always passes.

Usage

```
entisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`episaturation_usda` *Episaturation helper (USDA, KST 13ed Ch 3, p 41) Pass when aquic conditions PLUS perched water (saturation type "episaturation").*

Description

Episaturation helper (USDA, KST 13ed Ch 3, p 41) Pass when aquic conditions PLUS perched water (saturation type "episaturation").

Usage

```
episaturation_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`espodossolo` *Espodossolos (SiBCS Cap 4, p 112; conceito Cap 3, p 90-91)*

Description

Horizonte B espodico imediatamente abaixo de horizontes E ou A, dentro de 200 cm (ou 400 cm se A+E ou histico+E ultrapassam 200).

Usage

```
espodossolo(pedon, max_top_cm = 200)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`espodossolo_ferriluvico` *Espodossolos Ferriluvicos (Cap 8): B espodico tipo Bs (Fe + Al, baixo OC iluvial).*

Description

Espodossolos Ferriluvicos (Cap 8): B espodico tipo Bs (Fe + Al, baixo OC iluvial).

Usage

```
espodossolo_ferriluvico(pedon)
```

Arguments

pedon	A PedonRecord.

`espodossolo_ferri_humiluvico` *Espodossolos Ferri-humiluvicos (Cap 8): B espodico tipo Bhs OR catch-all dos espodossolos.*

Description

Espodossolos Ferri-humiluvicos (Cap 8): B espodico tipo Bhs OR catch-all dos espodossolos.

Usage

```
espodossolo_ferri_humiluvico(pedon)
```

Arguments

pedon	A PedonRecord.

espodossolo_humiluvico *Espodossolos Humiluvicos (Cap 8): B espodico tipo Bh (org. + Al, pouco/sem Fe).*

Description

Espodossolos Humiluvicos (Cap 8): B espodico tipo Bh (org. + Al, pouco/sem Fe).

Usage

```
espodossolo_humiluvico(pedon)
```

Arguments

pedon	A PedonRecord.

eutric_inceptisol_usda *Eutric Inceptisol Suborder helper (Eutrudepts) Pass when BS (NH4OAc) >= 60% in some part of upper 75 cm.*

Description

Eutric Inceptisol Suborder helper (Eutrudepts) Pass when BS (NH4OAc) >= 60% in some part of upper 75 cm.

Usage

```
eutric_inceptisol_usda(pedon, min_bs = 60)
```

Arguments

pedon	A PedonRecord.
min_bs	Numeric threshold or option (see Details).

`eutric_oxisol_usda` *Eutric Oxisol Suborder helper (Eutroperox/Eutrudox/etc.) Pass when BS (NH4OAc) >= 35% in all layers within 125 cm.*

Description

Eutric Oxisol Suborder helper (Eutroperox/Eutrudox/etc.) Pass when BS (NH4OAc) >= 35% in all layers within 125 cm.

Usage

```
eutric_oxisol_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`eutric_subgroup_usda` *Eutric Subgroup helper (Andisols) Pass when base_saturation (sum-of-cations) >= 50% in some part.*

Description

Eutric Subgroup helper (Andisols) Pass when base_saturation (sum-of-cations) >= 50% in some part.

Usage

```
eutric_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

eutrofico *Solo eutrofico (SiBCS Cap 1, p 30)*

Description

Returns TRUE se a saturacao por bases (V%) >= 50% no horizonte diagnostico subsuperficial (B ou C). 65% para A chernozemico.

Usage

```
eutrofico(pedon, min_v = 50)
```

Arguments

pedon	A `PedonRecord`.
min_v	Numeric threshold or option (see Details).

evaluate_rsg_tests *Evaluate the test block of a single RSG*

Description

Given a parsed `tests` block from a YAML key entry, evaluates the appropriate combinator and returns a list with `passed`, `evidence`, `missing`, and (optionally) `notes`.

Usage

```
evaluate_rsg_tests(pedon, tests)
```

Arguments

pedon	A `PedonRecord`.
tests	A `tests` block from the YAML.

Value

A list summarising the test outcome.

extract_horizons_from_pdf
Extract horizons from a soil description PDF

Description

Reads a PDF (typically a soil survey chapter, field-sheet scan, or thesis appendix), prompts the configured VLM to extract horizon attributes against `inst/schemas/horizon.json`, and merges the result into `pedon`. Every extracted attribute is recorded with `source = "extracted_vlm"` and the model's reported confidence and verbatim source quote.

Usage

```
extract_horizons_from_pdf(
  pedon,
  pdf_path = NULL,
  provider,
  max_retries = 3L,
  overwrite = FALSE,
  prompt_name = "extract_horizons",
  schema_name = "horizon",
  pdf_text = NULL
)
```

Arguments

`pedon`	A `PedonRecord` to merge into. Mutated in place AND returned invisibly.
`pdf_path`	Path to the PDF file. Either `pdf_path` or `pdf_text` must be supplied.
`provider`	A chat provider from `vlm_provider` (or a `MockVLMProvider` for testing).
`max_retries`	Integer; how many times to re-prompt on validation failure. Default 3.
`overwrite`	If `TRUE`, lower-authority values are allowed to clobber higher-authority ones. Default `FALSE`.
`prompt_name`	Override the default prompt template (`"extract_horizons"`).
`schema_name`	Override the default schema (`"horizon"`).
`pdf_text`	Optional alternative to `pdf_path`: the already-extracted description text. Useful for smoke tests, unit tests without `pdftools`, and for already-OCR'd field-sheet text.

Details

The PedonRecord's authority order guarantees that values already tagged `"measured"` are never silently overwritten by VLM extraction unless `overwrite = TRUE`.

If the PDF is long (more than ~30,000 characters), it is chunked page-by-page and each page is sent independently. This is a conservative-but-simple strategy; for very long surveys callers should pre-chunk and call this function once per profile.

Value

Invisibly, the (mutated) pedon. Carries a "vlm_extraction" attribute with the parsed response, number of attempts, and number of provenance entries added.

Failure modes

- If pdftools is not installed -> error.
- If the PDF cannot be read -> error.
- If the VLM response fails JSON parse / schema validation after max_retries + 1 attempts -> error from validate_or_retry.

---

extract_munsell_from_photo

Extract Munsell color from a profile photo

Description

Sends the photo to a multimodal VLM with a prompt that asks the model to estimate Munsell hue / value / chroma per visible horizon (when a Munsell reference card is in frame). Recorded as extracted_vlm with the model's self-reported confidence; photos without a reference card should yield confidence below 0.5 per the prompt specification.

Usage

```
extract_munsell_from_photo(
  pedon,
  image_path,
  provider,
  max_retries = 3L,
  overwrite = FALSE,
  prompt_name = "extract_munsell_from_photo",
  schema_name = "horizon"
)
```

Arguments

pedon	A PedonRecord.
image_path	Path to the image file (JPG / PNG).
provider	A chat provider from vlm_provider (or a MockVLMProvider for testing).
max_retries	Integer; how many times to re-prompt on validation failure. Default 3.
overwrite	If TRUE, lower-authority values are allowed to clobber higher-authority ones. Default FALSE.
prompt_name	Override the default prompt template ("extract_horizons").
schema_name	Override the default schema ("horizon").

Details

Quantitative non-color attributes (clay %, CEC, pH, etc.) are **never** extracted from photos, by prompt-level instruction. If the model returns one anyway, it is silently dropped.

Value

Invisibly, the mutated pedon, with the photo added to pedon$images.

---

extract_site_from_fieldsheet
Extract site metadata from a field-sheet image

Description

Sends a photographed / scanned field sheet to a multimodal VLM and merges the extracted site-level metadata (lat, lon, elevation, parent material, land use, etc.) into pedon$site. Existing fields are preserved unless overwrite = TRUE; only NULL fields are filled.

Usage

```
extract_site_from_fieldsheet(
  pedon,
  image_path,
  provider,
  max_retries = 3L,
  overwrite = FALSE,
  prompt_name = "extract_site_metadata",
  schema_name = "site"
)
```

Arguments

pedon	A PedonRecord.
image_path	Path to the field-sheet image.
provider	A chat provider from vlm_provider (or a MockVLMProvider for testing).
max_retries	Integer; how many times to re-prompt on validation failure. Default 3.
overwrite	If TRUE, lower-authority values are allowed to clobber higher-authority ones. Default FALSE.
prompt_name	Override the default prompt template ("extract_horizons").
schema_name	Override the default schema ("horizon").

Value

Invisibly, the mutated pedon.

`familia_andico` *Familia: propriedades andicas (Cap 1, p 42-43)*

Description

Aplica o termo "andico" quando, em qualquer horizonte:

- densidade do solo <= 0,9 g/cm3, E
- retencao de fosfato >= 85%, E
- Alo + 0.5 * Feo >= 2% (oxalato extraivel)

Usage

```
familia_andico(pedon, max_db = 0.9, min_pret = 85, min_aloxfeox = 2)
```

Arguments

`pedon`	A `PedonRecord`.
`max_db`	Densidade maxima (default 0.9 g/cm3).
`min_pret`	Retencao minima de fosfato (default 85%).
`min_aloxfeox`	Limite de Alo + 0.5*Feo (default 2%).

Details

Aplicavel para Cambissolos Histicos e Organossolos Folicos (Cap 18 p 287), em fase de validacao.

Value

`FamilyAttribute` com `value = "andico"` ou NULL.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 42-43; Cap 18, p 287.

familia_atividade_argila
Familia: subgrupamento de atividade da fracao argila (Cap 18, p 287)

Description

Classifica pela CTC da fracao argila T = (cec_cmol * 100 / clay_pct):

- `Tmb`: T < 8 cmolc/kg argila (muito baixa)
- `Tmob`: 8 <= T < 17 (moderadamente baixa)
- `Tm`: 17 <= T < 27 (media)
- `Tmoa`: 27 <= T < 40 (moderadamente alta)
- `Tma`: T >= 40 (muito alta)

Usage

```
familia_atividade_argila(pedon, max_depth_cm = 150)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade da secao de controle (default 150).

Details

Considerada na maior parte do horizonte B (ou C, na ausencia de B). Nao aplicavel a solos de classe textural areia ou areia franca (clay < 15 g kg-1 = 1,5%).

Value

FamilyAttribute.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 287.

familia_constituicao_esqueletica

Familia: constituicao esqueletica (Cap 1, p 48)

Description

Solo com mais de 35% e menos de 90% do volume constituido por material mineral com diametro > 2 cm. Acima de 90%, eh considerado tipo de terreno (nao classificavel).

Usage

```
familia_constituicao_esqueletica(pedon, max_depth_cm = 200)
```

Arguments

`pedon`	A `PedonRecord`.
`max_depth_cm`	Profundidade da secao de controle (default 200).

Details

O schema atual nao distingue cascalho (2 mm-2 cm) de calhaus (> 2 cm). Como aproximacao conservadora, esta funcao retorna "esqueletica" quando `coarse_fragments_pct` esta no intervalo (35%, 90%). Refinamento futuro requer adicionar uma coluna distinta para fragmentos > 2 cm.

Value

`FamilyAttribute`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 48; Cap 18, p 284.

familia_distribuicao_cascalhos

Familia: distribuicao de cascalhos no perfil (Cap 1, p 47-48)

Description

Utiliza coarse_fragments_pct (% volume de cascalhos 2 mm a 2 cm relativo a terra fina) como modificador do grupamento textural.

Usage

```
familia_distribuicao_cascalhos(pedon, max_depth_cm = 200)
```

Arguments

pedon A `PedonRecord`.

max_depth_cm Profundidade da secao de controle (default 200).

Details

Classes (Santos et al., 2015; valores em g kg-1):

- pouco_cascalhenta: 8% <= cascalho < 15%
- cascalhenta: 15% <= cascalho <= 50%
- muito_cascalhenta: cascalho > 50%

Aplica-se a TODAS as classes que apresentam cascalho > 80 g/kg (8% do volume) na secao de controle.

Value

`FamilyAttribute`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 47-48; Cap 18, p 284.

`familia_grupamento_textural` *Familia: grupamento textural (Cap 1, p 46)*

Description

Retorna o grupamento textural do solo na secao de controle. Classes (em g kg-1):

- arenosa: areia + areia franca, i.e. (sand_pct - clay_pct) > 70
- media: clay < 35 e sand > 15, exceto arenosa
- argilosa: clay entre 35 e 60
- muito_argilosa: clay > 60
- siltosa: clay < 35 e sand < 15

Usage

```
familia_grupamento_textural(pedon, max_depth_cm = 200)
```

Arguments

pedon A `PedonRecord`.

max_depth_cm Profundidade da secao de controle (default 200 cm).

Details

Aplicavel a todas as ordens do SiBCS, exceto Neossolos Quartzarenicos (RQ), nas quais o subgrupamento eh mais apropriado.

Value

FamilyAttribute.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p. 46-47; Cap 18, p. 281.

---

familia_label — *Constroi label textual de Familia a partir de* classify_sibcs_familia

---

Description

Concatena os value nao-nulos como string separada por virgulas, conforme orientado no Cap 18, p 281: "as caracteristicas utilizadas para identificacao do 5o nivel categorico devem ser acrescentadas apos a designacao do 4o nivel categorico e separadas desta e entre si por virgula".

Usage

```
familia_label(familia)
```

Arguments

familia	Lista de FamilyAttribute, retorno de classify_sibcs_familia.

Value

String com adjetivos compostos separados por ", ", ou vazia se nenhum adjetivo se aplica.

---

familia_mineralogia_areia — *Familia: mineralogia da fracao areia (Cap 18, p 286)*

Description

Identifica predominio de minerais facilmente alteraveis na fracao areia (>= 0,05 mm) na secao de controle. Classes:

- micacea: sand_mica_pct >= 15 (% volume).
- anfibolitica: sand_amphibole_pct >= 15.
- feldspatica: sand_feldspar_pct >= 15.

Usage

```
familia_mineralogia_areia(pedon, max_depth_cm = 200, threshold = 15)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade da secao de controle (default 200).
threshold	Limiar de % volume (default 15).

Details

Quando os percentuais especificos estao ausentes, busca a coluna `sand_mineralogy` (atalho qualitativo, valores aceitos: "micacea", "anfibolitica", "feldspatica").

Aplicavel a Cambissolos, Chernossolos, Gleissolos, Luvissolos, Neossolos (excepto Quartzarenicos), Nitossolos, Planossolos, Plintossolos e Vertissolos.

Value

FamilyAttribute.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 286.

---

familia_mineralogia_argila_geral

Familia: mineralogia da fracao argila (geral, nao-Latossolos)

Description

Classifica a mineralogia da argila para Argissolos, Cambissolos, Plintossolos, Luvissolos, Nitossolos, Vertissolos, Chernossolos, Planossolos, Gleissolos quando ha informacao quantitativa de atividade da argila e/ou Ki/Kr. Cobre as classes nao endereçadas por `familia_mineralogia_argila_latossolo`:

- `esmectitica`: T_argila >= `ta_threshold` (default 27 cmolc/kg argila), indicando dominancia de argilas 2:1 expansivas (esmectita / vermiculita / micas hidratadas).
- `caulinitica`: Ki >= `ki_caulinitico_min` (default 0.75) e Kr >= `kr_caulinitico_min` (default 0.75), alem de T_argila < `ta_threshold`.
- `oxidica`: Kr < `kr_caulinitico_min`, indicando predominancia de oxihidrooxidos de Fe e Al.
- `mista`: nenhum dos outros gates fechou conclusivamente – evidencia heterogenea ou incompleta.

Quando os tres atributos (T_argila, Ki, Kr) estiverem ausentes, o resultado fica `NULL` e os atributos faltantes sao reportados.

Usage

```
familia_mineralogia_argila_geral(
  pedon,
  max_depth_cm = 200,
  ta_threshold = 27,
  ki_caulinitico_min = 0.75,
  kr_caulinitico_min = 0.75
)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade da secao de controle (default 200).
ta_threshold	Limite cmolc/kg argila para esmectitica (default 27).
ki_caulinitico_min	Limite Ki para caulinitica (default 0.75).
kr_caulinitico_min	Limite Kr para caulinitica vs oxidica (default 0.75).

Value

FamilyAttribute.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 286-287.

---

familia_mineralogia_argila_latossolo

Familia: mineralogia da fracao argila para Latossolos (Cap 18, p 286-287)

Description

Classifica via Ki = SiO2/(Al2O3) e Kr = SiO2/(Al2O3 + Fe2O3) molares (helpers compute_ki / compute_kr):

- caulinitico: Ki > 0.75 e Kr > 0.75
- caulinitico-oxidico: Ki > 0.75 e Kr <= 0.75
- gibsitico-oxidico: Ki <= 0.75 e Kr <= 0.75
- oxidico: Kr <= 0.75 (predominio Fe2O3 + Al2O3)

Usage

```
familia_mineralogia_argila_latossolo(pedon, max_depth_cm = 200)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade da secao de controle (default 200).

Details

Aplicavel principalmente para Latossolos; tambem pode ser usado em Argissolos, Cambissolos e Plintossolos quando ha informacao de mineralogia da argila pelo menos semiquantitativa.

Value

FamilyAttribute.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 286-287.

---

familia_organossolo_espessura

Familia: espessura > 100 cm de material organico em Organossolos (Cap 18, p 287)

Description

Retorna "espesso" quando a soma das espessuras de camadas organicas a partir da superficie excede 100 cm (Cap 18 p 287: "Organossolos com mais de 100 cm de material organico a partir da sua superficie").

Usage

```
familia_organossolo_espessura(pedon, min_cm = 100)
```

Arguments

pedon	A PedonRecord.
min_cm	Default 100 cm.

Value

FamilyAttribute.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 287.

`familia_organossolo_lenhosidade`
Familia: lenhosidade em Organossolos (Cap 18, p 288)

Description

Classifica a presenca de galhos / fragmentos de troncos > 2 cm em camadas organicas, "a semelhanca do utilizado para qualificar as classes de pedregosidade" (Cap 18 p 288):

- `lenhoso`: 10% <= woody_fragments < 30%
- `muito_lenhoso`: 30% <= woody_fragments <= 50%
- `extremamente_lenhoso`: woody_fragments > 50%

(Limites adotados a partir das classes de pedregosidade, Santos et al. 2015.)

Usage

```
familia_organossolo_lenhosidade(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

`FamilyAttribute`.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 288.

`familia_organossolo_material_subjacente`
Familia: material subjacente em Organossolos (Cap 18, p 287)

Description

Identifica a textura da primeira camada nao-organica abaixo das camadas organicas, na secao de controle. Retorna o grupamento textural daquele material como adjetivo (e.g. "arenoso", "argiloso").

Usage

```
familia_organossolo_material_subjacente(pedon, max_depth_cm = 200)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade da secao de controle (default 200).

Value

FamilyAttribute.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 287.

---

familia_oxidos_ferro *Familia: teor de oxidos de ferro (Cap 1, p 42)*

Description

Classifica pelo teor de Fe2O3 (g/kg de solo, equivalente a fe2o3_sulfuric_pct * 10) na maior parte do horizonte B:

- hipoferrico: < 80 g/kg (= < 8%)
- mesoferrico: 80 - 180 g/kg ([8%, 18%))
- ferrico: 180 - 360 g/kg ([18%, 36%))
- perferrico: >= 360 g/kg (>= 36%)

Usage

```
familia_oxidos_ferro(pedon, max_depth_cm = 150)
```

Arguments

pedon	A PedonRecord.
max_depth_cm	Profundidade da secao de controle (default 150).

Details

Aplicavel a Argissolos, Cambissolos, Chernossolos, Latossolos, Neossolos Litolicos, Neossolos Regoliticos, Nitossolos e Plintossolos. Quando o atributo ja foi considerado em nivel categorico mais alto (e.g. Latossolos Eutroferricos / Distroferricos / Acriferricos), o motor de Familia pula esta dimensao.

Value

FamilyAttribute.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 42.

familia_prefixo_profundidade *Familia: prefixo de profundidade epi-/meso-/endo- (Cap 18, p 284-285)*

Description

Classifica a profundidade onde um diagnostico ocorre em um dos tres prefixos:

- `epi-`: topo da primeira camada que satisfaz < 50 cm
- `meso-`: topo da primeira camada em [50, 100) cm
- `endo-`: topo da primeira camada em >= 100 cm

Usage

```
familia_prefixo_profundidade(diag, horizons)
```

Arguments

`diag`	Um `DiagnosticResult` com `layers` (indices de horizontes que satisfazem o atributo).
`horizons`	`data.table` de horizontes do pedon.

Details

Wrapper generico para ser usado com qualquer `DiagnosticResult`. Retorna NULL se o diagnostico nao passou ou se nao ha camadas identificadas.

Value

String "epi" / "meso" / "endo" ou NULL.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 284-285.

familia_saturacao_aluminio

Familia: saturacao por aluminio – "alico" (Cap 18, p 285)

Description

Aplica o termo "alico" quando, em qualquer camada do horizonte B (ou C, na ausencia de B):

- al_sat_pct >= 50% (saturacao por Al = 100*Al/(S+Al)),
- E al_cmol > 0.5 cmolc/kg.

Quando aplicavel, o prefixo de profundidade (epi-/meso-/endo-) eh determinado pelo topo da primeira camada que satisfaz, e concatenado ao adjetivo: "epialico", "mesoalico", "endoalico".

Usage

```
familia_saturacao_aluminio(pedon, min_al_sat = 50, min_al_cmol = 0.5)
```

Arguments

`pedon`	A `PedonRecord`.
`min_al_sat`	Default 50.
`min_al_cmol`	Default 0.5.

Details

Aplicavel a classes cujo carater alumınico nao tenha sido considerado em nivel categorico mais alto (p.ex. Argissolos Aluminicos ja o usam).

Value

`FamilyAttribute` com value igual a `"epialico"` / `"mesoalico"` / `"endoalico"` ou NULL.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p 285.

`familia_saturacao_bases`
Familia: saturacao por bases (Cap 18, p 285)

Description

Retorna "`eutrofico`" (V >= 50%) ou "`distrofico`" (V < 50%) baseado na media ponderada de `bs_pct` na secao de controle. Pode ser combinado com prefixos epi-/meso-/endo- via `familia_prefixo_profundidade`.

Usage

```
familia_saturacao_bases(pedon, max_depth_cm = 150, threshold = 50)
```

Arguments

`pedon`	A `PedonRecord`.
`max_depth_cm`	Profundidade da secao de controle (default 150 cm; p. 31 do SiBCS define a secao de controle dos Argissolos / Latossolos como 0-150 cm de B).
`threshold`	Limiar de eutrofico (default 50%).

Details

Aplicavel a todas as classes que ainda nao consideram saturacao por bases em nivel categorico mais alto (p.ex. Latossolos Eutroficos / Distroficos ja a consideram).

Value

`FamilyAttribute`.

References

Embrapa (2018), SiBCS 5a ed., Cap 1, p 31; Cap 18, p 285.

`familia_subgrupamento_textural`
Familia: subgrupamento textural (Cap 18, p 283; em validacao)

Description

Subgrupamento textural mais detalhado, aplicavel em substituicao ao grupamento para Espodossolos, Latossolos psamiticos, Neossolos Fluvicos Psamiticos, Neossolos Regoliticos, Neossolos Quartzarenicos, e SGs arenicos / espessarenicos de Argissolos / Luvissolos / Planossolos / Plintossolos. Tambem em solos com textura arenosa e/ou media.

Usage

```
familia_subgrupamento_textural(pedon, max_depth_cm = 200)
```

Arguments

`pedon`	A `PedonRecord`.
`max_depth_cm`	Profundidade da secao de controle (default 200 cm).

Details

Classes (em g kg-1; referidas a media ponderada da secao de controle):

- muito_arenosa: classe textural areia (sand >= 85)
- arenosa-media: classe textural areia franca (sand >= 70 e <= 91; clay <= 15)
- media-arenosa: francoarenosa, sand > 52
- media-argilosa: franco-argiloarenosa (clay 20-35, sand >= 45)
- media-siltosa: clay < 35 e sand > 15, excluindo as 4 classes acima
- siltosa: clay < 35 e sand < 15
- argilosa: clay 35-60
- muito_argilosa: clay > 60

Value

`FamilyAttribute`.

References

Embrapa (2018), SiBCS 5a ed., Cap 18, p. 283.

`familia_tipo_horizonte_superficial`
Familia: tipo de horizonte diagnostico superficial (Cap 2)

Description

Retorna o tipo do horizonte A (ou H/O) presente, em ordem de precedencia: `histico` > `chernozemico` > `humico` > `proeminente` > `moderado` > `fraco`. Se nenhum diagnostico passa, retorna NULL.

Usage

```
familia_tipo_horizonte_superficial(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Details

Aplica-se a TODAS as classes de solo, exceto para aquelas que ja consideram o tipo de A em nivel categorico mais alto (e.g. Chernossolos, Organossolos, Neossolos Litolicos Humicos / Histicos).

Value

`FamilyAttribute`.

References

Embrapa (2018), SiBCS 5a ed., Cap 2 (p 49-54); Cap 18, p 284.

`FamilyAttribute` *Classe S4-like para atributos de Familia (5o nivel SiBCS)*

Description

Classe S4-like para atributos de Familia (5o nivel SiBCS)

Classe S4-like para atributos de Familia (5o nivel SiBCS)

Details

Estrutura categorica (em vez de booleana) que representa um adjetivo composto da Familia. `value` eh o adjetivo atribuido (string) ou `NULL` quando a dimensao nao se aplica ou nao foi possivel determinar.

Public fields

`name` Nome da dimensao (e.g. "grupamento_textural").

`value` Adjetivo atribuido (e.g. "argilosa") ou NULL.

`evidence` Lista nomeada com valores intermediarios.

`missing` Vetor de colunas necessarias mas indisponiveis.

`reference` String com referencia bibliografica.

Methods

Public methods:

- `FamilyAttribute$new()`
- `FamilyAttribute$print()`
- `FamilyAttribute$clone()`

Method `new()`**:** Build a FamilyAttribute.

Usage:

```
FamilyAttribute$new(
  name,
  value = NULL,
  evidence = list(),
  missing = character(0),
  reference = ""
)
```

Arguments:

`name` Nome da dimensao (e.g. "grupamento_textural").

`value` Adjetivo atribuido (e.g. "argilosa") ou `NULL`.

`evidence` Lista nomeada com valores intermediarios.

`missing` Vetor de colunas necessarias mas indisponiveis.

`reference` String com referencia bibliografica.

Method `print()`**:** Pretty-print the attribute.

Usage:

```
FamilyAttribute$print(...)
```

Arguments:

`...` Ignored (S3 print signature compatibility).

Method `clone()`**:** The objects of this class are cloneable with this method.

Usage:

```
FamilyAttribute$clone(deep = FALSE)
```

Arguments:

`deep` Whether to make a deep clone.

`febr_index_munsell` *Curated index of FEBR datasets that carry Munsell colors*

Description

Returns a data.frame listing FEBR dataset IDs that have at least one Munsell-related column populated in their `camada` table, with metadata: `n_horizons`, `n_finite_munsell`, `coverage`, `column_pattern`.

Usage

```
febr_index_munsell(min_coverage = 0.1, refresh = FALSE, verbose = TRUE)
```

Arguments

`min_coverage`	Drop datasets whose Munsell coverage (fraction of horizons with non-NA hue) is below this. Default 0.1.
`refresh`	Logical. If `TRUE`, re-scan FEBR over the network instead of using the bundled May-2026 cache.
`verbose`	If `TRUE` (default), prints a one-line summary.

Details

Backed by a precomputed cache shipped in `R/sysdata.rda` (`.FEBR_MUNSELL_INDEX`; results of the May 2026 scan over 249 datasets). On first call after install, returns the cache instantly. Pass `refresh = TRUE` to re-scan FEBR live (slow, network-dependent; updates the in-memory copy but does not modify the bundled cache).

Value

A `data.frame` sorted by `n_finite_munsell` descending.

See Also

`read_febr_pedons`.

---

ferralic — *Ferralic horizon (WRB 2022)*

Description

Tests whether any horizon meets the ferralic horizon criteria. The ferralic horizon is a subsurface horizon resulting from long and intense weathering, characterized by very low cation exchange capacity per unit clay – the canonical "low-activity clay" signal that defines the Ferralsol RSG.

Usage

```
ferralic(pedon, min_thickness = 30, max_cec = NULL, engine = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness in cm (default 30).
`max_cec`	Maximum CEC (1M NH4OAc, pH 7) per kg clay (default `NULL` = 16 in soilkey engine, 20 in aqp engine; see `engine`).
`engine`	One of `"soilkey"` (default; strict 16 cmol_c/kg-clay threshold per WRB 2022) or `"aqp"` (relaxed 20 cmol_c/kg-clay – a regional tolerance that accommodates Brazilian / SOTERLAC Latossolos data, where Embrapa-style Mehlich/Ca+Mg+K+Al sum often reads ~17-20 on profiles that the canonical NRCS / WRB definition would accept as ferralic). `NULL` reads `getOption("soilKey.diagnostic_engine")`. The numeric threshold can also be overridden directly via `options(soilKey.ferralic_max_cec = ...)`.

Details

Sub-tests called:

- `test_ferralic_texture` – texture sandy loam or finer.
- `test_cec_per_clay` – CEC / clay <= 16 (or 20 under `engine = "aqp"`) cmol_c/kg clay.
- `test_ferralic_thickness` – thickness >= 30 cm.

v0.3.1 alignment with WRB 2022 Ch 3.1.10 (p. 44): the older "ECEC <= 12 cmol_c/kg clay" gate was removed because it is not in the canonical text – only CEC (1M NH4OAc, pH 7) <= 16 is required.

v0.9.67 regional tolerance: BDsolos RJ benchmark (n=722 perfis) showed 88/115 Latossolos failing the strict 16-cmol gate because Embrapa lab methodology often reads CEC at 17-20 on profiles that are unambiguously Latossolos by every other criterion. The `engine = "aqp"` threshold of 20 closes that gap without redefining the WRB threshold itself; users targeting strict WRB 2022 fidelity should keep `engine = "soilkey"`.

The weatherable-mineral test (<= 10% by volume), water-dispersible-clay test, and stratification / rock-structure exclusions remain deferred (they need mineralogical data outside the canonical horizon schema) and are refinements rather than gates.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022). *World Reference Base for Soil Resources*, 4th edition. International Union of Soil Sciences, Vienna. Chapter 3.1.10 – Ferralic horizon (p. 44).

`ferralsol` *Ferralsol RSG gate (WRB 2022 Ch 4, p 110)*

Description

WRB-canonical: ferralic horizon \<= 150 cm AND no argic horizon starting above (or at the upper limit of) the ferralic, UNLESS the argic in its upper 30 cm or throughout has one or more of:

- < 10% water-dispersible clay; OR
- DeltapH (pH_KCl - pH_water) \>= 0; OR
- \>= 1.4% soil organic carbon.

v0.3.4 enforces all three exception paths. The DeltapH check uses `ph_kcl` and `ph_h2o`; the WDC check uses `water_dispersible_clay_pct` (introduced in v0.3.3 schema).

Usage

```
ferralsol(pedon)
```

Arguments

pedon A PedonRecord.

---

ferric *Ferric horizon (WRB 2022)*

Description

A horizon of iron accumulation that does not reach the cementation / redness levels of plinthic. Diagnostic for the Ferric qualifier.

Usage

```
ferric(pedon, min_thickness = 15, min_fe_dith_pct = 5)
```

Arguments

pedon	A PedonRecord.
min_thickness	Minimum thickness (cm; default 15).
min_fe_dith_pct	Minimum dithionite-extractable iron percent (default 5).

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 3.1, Ferric horizon.

---

ferric_subgroup_usda *Ferric Subgroup helper (Ferrudalfs) Pass when iron-rich (fe_dcb_pct >= 4%) horizon present in B.*

Description

Ferric Subgroup helper (Ferrudalfs) Pass when iron-rich (fe_dcb_pct >= 4%) horizon present in B.

Usage

```
ferric_subgroup_usda(pedon)
```

Arguments

pedon A PedonRecord.

fibrico — *Material organico fibrico (SiBCS Cap 14)*

Description

Material organico pouco decomposto: >= 40% de fibras esfregadas OU indice de von Post H1-H4. Discrimina Organossolos Fibricos no 3o nivel.

Usage

```
fibrico(pedon)
```

Arguments

pedon	A PedonRecord.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 14 (Organossolos), pp 224-226.

fibric_predominant_usda — *Fibric_predominant_usda: Fibrists Suborder qualifier*

Description

Fibric_predominant_usda: Fibrists Suborder qualifier

Usage

```
fibric_predominant_usda(pedon)
```

Arguments

pedon	A PedonRecord.

fibric_subgroup_usda *Fibric Subgroup helper (Haplohemists / Haplowassists / Sulfiwassists) Pass when fibric layers cumulative thickness >= 25 cm in control section below surface tier.*

Description

Fibric Subgroup helper (Haplohemists / Haplowassists / Sulfiwassists) Pass when fibric layers cumulative thickness >= 25 cm in control section below surface tier.

Usage

```
fibric_subgroup_usda(pedon, max_top_cm = 130)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Numeric threshold or option (see Details).

---

fill_from_spectra *Fill missing soil attributes from spectra via OSSL*

Description

Given a PedonRecord carrying a `spectra$vnir` matrix (rows = horizons, columns = wavelengths in nm), pre-processes the spectra, predicts the requested soil properties using the chosen OSSL-backed method, and writes the predictions into the pedon's horizons table via `pedon$add_measurement(..., source = "predicted_spectra")`. Each call updates the pedon's provenance log so that downstream classification can derive an evidence grade.

Usage

```
fill_from_spectra(
  pedon,
  library = "ossl",
  region = c("global", "south_america", "north_america", "europe", "africa"),
 properties = c("clay_pct", "sand_pct", "silt_pct", "cec_cmol", "bs_pct", "ph_h2o",
   "oc_pct", "fe_dcb_pct", "caco3_pct"),
  method = c("mbl", "plsr_local", "pretrained"),
  preprocess = "snv+sg1",
  k_neighbors = 100L,
  overwrite = FALSE,
  ossl_library = NULL,
  ossl_models = NULL,
  verbose = TRUE
)
```

Arguments

pedon	A PedonRecord with a spectra$vnir matrix.
library	Currently only "ossl" is supported.
region	One of "global", "south_america", "north_america", "europe", "africa". Used to subset the OSSL training data when supported by the underlying back-end.
properties	Character vector of OSSL-supported property names to predict. Default covers the most-requested WRB/SiBCS-relevant attributes.
method	One of "mbl", "plsr_local", "pretrained".
preprocess	Pre-processing pipeline; passed to preprocess_spectra.
k_neighbors	Number of neighbours for memory-based methods.
overwrite	If FALSE (default), only fill cells whose existing provenance is weaker than predicted_spectra.
ossl_library	Optional OSSL library object (see predict_ossl_mbl).
ossl_models	Optional named list of pretrained models (see predict_ossl_pretrained).
verbose	If TRUE, prints a cli summary.

Details

By default, predicted values do **not** overwrite measured values (the add_measurement() authority logic protects them). Setting overwrite = TRUE forces overwrite of any non-measured value.

Value

The mutated pedon, invisibly. Provenance entries with source = "predicted_spectra" are added per (horizon, property).

See Also

preprocess_spectra, predict_ossl_mbl, predict_ossl_plsr_local, predict_ossl_pretrained, pi_to_confidence.

---

fill_munsell_from_spectra

Fill missing Munsell colors on a PedonRecord from Vis-NIR spectra

---

Description

High-level helper that runs predict_munsell_from_spectra per horizon over the Vis-NIR spectra in pedon$spectra$vnir and writes the resulting hue / value / chroma back to the matching horizon rows via pedon$add_measurement(..., source = "predicted_spectra").

Usage

```
fill_munsell_from_spectra(pedon, overwrite = FALSE, verbose = TRUE)
```

Arguments

pedon	A PedonRecord that has $spectra$vnir populated (rows = horizons, cols = wavelengths).
overwrite	If TRUE, overwrite existing Munsell measurements. Default FALSE (only fills horizons whose Munsell is currently NA).
verbose	If TRUE (default), prints a per-horizon summary.

Details

This is the operational answer to the v0.9.35 Argissolo color confusion: when surveyor Munsell colors are missing and the user has Vis-NIR (e.g. from OSSL), call this helper, then re-run classify_sibcs – the v0.9.45 "color-undetermined" fallback will lift, and the classification will descend to subordem / grande grupo / subgrupo with proper evidence_grade.

Value

The pedon, invisibly. Provenance entries with source = "predicted_spectra" are appended.

---

fluvaquentic_usda *Fluvaquentic Subgroup helper (irregular OC decrease + aquic)*

Description

Pass when:

- Irregular decrease in organic carbon between 25 cm and 125 cm (or to a densic/lithic/paralithic contact); AND
- Aquic conditions in some horizon within 75 cm (aquic_conditions_usda(pedon, max_top_cm = 75)).

Usage

```
fluvaquentic_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation: tests whether OC values are non-monotonic (some upward variation) within 25-125 cm.

Value

A DiagnosticResult.

References

Soil Survey Staff (2022), KST 13ed, Ch. 9.

`fluventic_usda` *Fluventic Subgroup helper (irregular OC decrease, NO aquic req.)*

Description

Fluventic Subgroup helper (irregular OC decrease, NO aquic req.)

Usage

```
fluventic_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

A `DiagnosticResult`.

`fluvent_qualifying_usda` *Fluvent Suborder qualifier (irregular OC decrease in 25-125 cm, OR layered alluvial designation).*

Description

Fluvent Suborder qualifier (irregular OC decrease in 25-125 cm, OR layered alluvial designation).

Usage

```
fluvent_qualifying_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

fluvic_material *Fluvic material (WRB 2022)*

Description

Tests whether the profile shows fluvic material features: alternating textures across consecutive horizons within the upper 100 cm AND an irregular (non-monotone) organic carbon pattern with depth. Diagnostic of Fluvisols.

Usage

```
fluvic_material(pedon, max_top_cm = 100, min_clay_swing = 8)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Maximum top depth (cm) considered (default 100).
min_clay_swing	Minimum absolute clay-percent change between consecutive layers required to count as alternation (default 8 percentage points).

Details

Sub-test: test_fluvic_stratification.

v0.3 limitations: WRB 2022 fluvic material also requires age (typically <100 years for sediment freshness), which v0.3 does not check (no temporal fields in the schema). The stratification proxy is conservative – truly heterogeneous floodplain profiles with dramatic texture swings will pass; subtle alluvial sequences may miss. v0.4 will refine.

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 3, Fluvic material.

`folistic_epipedon_usda`

Folistic epipedon (USDA Soil Taxonomy, 13th edition)

Description

A freely-drained surface organic horizon. Differs from the histic epipedon in that it is saturated for less than 30 days per year. Diagnostic for the Folists suborder of Histosols and the Folistels great group of Histels.

Usage

```
folistic_epipedon_usda(pedon, min_oc_pct = 12, min_thickness_cm = 15)
```

Arguments

`pedon`	A `PedonRecord`.
`min_oc_pct`	Minimum OC for organic soil material (default 12).
`min_thickness_cm`	Minimum thickness (default 15 cm).

Details

KST 13ed required characteristics (Ch. 3, pp 13-14):

- Saturated < 30 days/year (and not artificially drained); AND
- Organic soil material: 15+ cm thick (with Sphagnum-rich exception 20-60 cm) OR Ap with OC >= 8 percent.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, pp 13-14.

`folistic_subgroup_usda` *Folistic Subgroup helper (folistic_epipedon present)*

Description

Folistic Subgroup helper (folistic_epipedon present)

Usage

```
folistic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

`folist_qualifying_usda` *Folists Suborder qualifier (KST 13ed, Ch 10, p 200)*

Description

Histosols saturated for less than 30 days per year (and not artificially drained). Implementation: pass when there is no aquic conditions and no glei designation in the upper 50 cm.

Usage

```
folist_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

`format_wrb_name` *Format a WRB 2022 soil name with qualifiers*

Description

Format a WRB 2022 soil name with qualifiers

Usage

```
format_wrb_name(
  rsg_name,
  principal = character(0),
  supplementary = character(0)
)
```

Arguments

`rsg_name`	Full RSG name (e.g. "Ferralsols").
`principal`	Character vector of principal-qualifier names.
`supplementary`	Character vector of supplementary-qualifier names (default empty in v0.9).

Value

Formatted string per Ch 6 p 154 ("Rhodic Ferralsol (Clayic, Humic, Dystric)").

`fragic` *Fragic horizon (WRB 2022): a high-bulk-density horizon with restricted rooting. v0.3.3: detects via bulk_density_g_cm3 >= 1.65 AND structure grade massive/very firm OR designation pattern* `x/Bx`.

Description

Fragic horizon (WRB 2022): a high-bulk-density horizon with restricted rooting. v0.3.3: detects via bulk_density_g_cm3 >= 1.65 AND structure grade massive/very firm OR designation pattern `x/Bx`.

Usage

```
fragic(pedon, min_thickness = 15, min_bd = 1.65)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).
`min_bd`	Numeric threshold or option (see Details).

`fragipa` *Fragipa (SiBCS Cap 2, p 73-74; v0.7)*

Description

Reuso de `fragic` (WRB v0.3.3): horizonte subsuperficial endurecido quando seco, baixa MO, BD elevada, quebradicidade.

Usage

```
fragipa(pedon, ...)
```

Arguments

`pedon`	A `PedonRecord`.
`...`	Reserved for future arguments.

`fragipan_usda` *Fragipan (USDA, KST 13ed Ch 3, p 38)*

Description

Pass when a horizon has fragic soil properties:

- rupture_resistance class >= "firm" (firm, very firm, extremely firm); OR
- NASIS pediagfeatures has a "Fragipan" entry (v0.9.31: the surveyor's field-identified fragipan – direct evidence, used as a tie-breaker when rupture_resistance is missing from the lab data); AND
- thickness >= 15 cm.

KSSL pedons rarely carry rupture_resistance; NASIS pediagfeatures carries 13 500 entries including "Fragipan" tags from surveyors. v0.9.31 adds the NASIS path so fragipan can be detected on KSSL+ NASIS pedons (closing the Fragiudults / Fragiudalfs / Fragiaqualfs confusion documented in the v0.9.25 Great Group analysis).

Usage

```
fragipan_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Default 100.

Value

A `DiagnosticResult`.

`frasic_qualifying_usda` *Frasiwassists Subgroup helper (Wassists)*

Description

Pass when ec_dS_m < 0.6 (1:5 soil:water) in all horizons within 100 cm. KST 13ed, Ch 10, p 203.

Usage

```
frasic_qualifying_usda(pedon, max_ec = 0.6, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_ec`	Default 0.6.
`max_top_cm`	Default 100.

Value

A `DiagnosticResult`.

`from_aqp` *Convert an aqp SoilProfileCollection back to a list of PedonRecord*

Description

Inverse of `as_aqp`. Walks each profile in the SPC, renames aqp's canonical horizon column names back to soilKey's (`top -> top_cm`, `name -> designation`, `clay -> clay_pct`, ...), assembles a `PedonRecord` per profile, and returns the list.

Usage

```
from_aqp(spc)
```

Arguments

`spc`	A `aqp::SoilProfileCollection`.

Details

Round-trip property: `from_aqp(as_aqp(pedon))` reproduces pedon modulo column ordering.

Value

A list of `PedonRecord` objects (length = `length(spc)`).

See Also

as_aqp, the forward conversion.

Examples

```
if (requireNamespace("aqp", quietly = TRUE)) {
  pedons <- list(make_ferralsol_canonical(), make_luvisol_canonical())
  spc <- as_aqp(pedons)
  pedons2 <- from_aqp(spc)
  identical(pedons[[1]]$horizons$clay_pct, pedons2[[1]]$horizons$clay_pct)
  #> [1] TRUE
}
```

---

fulvic_andisol_usda — *Fulvic Andisols: similar to melanic but with melanic_index > 1.70 (more humic acid). v0.8: detected via OC >= 6 in cumulative 30 cm but WITHOUT melanic_epipedon (since melanic requires index <= 1.70).*

Description

Fulvic Andisols: similar to melanic but with melanic_index > 1.70 (more humic acid). v0.8: detected via OC >= 6 in cumulative 30 cm but WITHOUT melanic_epipedon (since melanic requires index <= 1.70).

Usage

```
fulvic_andisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

gelisol_usda — *Gelisols (USDA Cap 9): gelic conditions / permafrost.*

Description

Order-level gate: cryic_conditions diagnostic from WRB delegated + optional permafrost_temp_C if available.

Usage

```
gelisol_usda(pedon)
```

Arguments

pedon A `PedonRecord`.

`glacic_layer_usda` *Glacic layer (USDA Soil Taxonomy, 13th edition)*

Description

"A glacic layer is massive ice or ground ice in the form of ice lenses or wedges. The layer is 30 cm or more thick and contains 75 percent or more visible ice." – KST 13ed, Ch 3, p 45.

Usage

```
glacic_layer_usda(pedon, max_top_cm = 100, min_thickness_cm = 30)
```

Arguments

pedon A `PedonRecord`.

max_top_cm Maximum top depth (default 100 cm; subgroup-level depth bound).

min_thickness_cm
Minimum thickness (default 30 cm).

Details

Diagnostic for the Glacistels great group of Histels and the Glacic subgroup modifier in Gelisols.

Implementation (v0.8.x): Detected via designation containing 'ff' (massive ice) per KST notation, with thickness >= 30 cm. Refinement to use an `ice_pct` schema column is deferred to v0.9.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, p 45.

`gleissolo` *Gleissolos (SiBCS Cap 4, p 112-113; conceito Cap 3, p 91-93)*

Description

Horizonte glei iniciando \<= 50 cm OR entre 50-150 cm imediatamente subjacente a A/E ou H histico (com espessura insuficiente para Organossolo), sem horizonte plintico/concrecionario/litoplintico dentro de 200 cm.

Usage

```
gleissolo(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`gleissolo_haplico` *Gleissolos Haplicos (catch-all).*

Description

Gleissolos Haplicos (catch-all).

Usage

```
gleissolo_haplico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`gleissolo_melanico` *Gleissolos Melanicos (Cap 9): horizonte hístico < 40 cm OR A humico, proeminente, chernozemico.*

Description

Gleissolos Melanicos (Cap 9): horizonte hístico < 40 cm OR A humico, proeminente, chernozemico.

Usage

```
gleissolo_melanico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

gleissolo_salico *Gleissolos Salicos (Cap 9): caracter salico em < 100 cm.*

Description

Gleissolos Salicos (Cap 9): caracter salico em < 100 cm.

Usage

```
gleissolo_salico(pedon)
```

Arguments

pedon	A PedonRecord.

gleissolo_tiomorfico *Gleissolos Tiomorficos (Cap 9): materiais sulfidricos OR horizonte sulfurico em < 100 cm.*

Description

Gleissolos Tiomorficos (Cap 9): materiais sulfidricos OR horizonte sulfurico em < 100 cm.

Usage

```
gleissolo_tiomorfico(pedon)
```

Arguments

pedon	A PedonRecord.

gleyic_properties *Gleyic properties (WRB 2022)*

Description

Tests whether the profile shows gleyic properties – evidence of prolonged saturation by groundwater – within the upper 50 cm. Gleyic properties are diagnostic for Gleysols and qualify many other RSGs (Endogleyic, Epigleyic qualifiers).

Usage

```
gleyic_properties(
  pedon,
  max_top_cm = 50,
  min_redox_pct = 5,
  stagnic_decay_factor = 3
)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Maximum top depth (cm) of a candidate layer (default 50, per WRB 2022).
min_redox_pct	Minimum redoximorphic_features_pct (default 5).
stagnic_decay_factor	Numeric threshold or option (see Details).

Details

Sub-test: test_gleyic_features – requires explicit redoximorphic_features_pct >= 5% within the upper 50 cm.

v0.2 deliberately does NOT use the Munsell-based shortcut (chroma <= 2 + value >= 4) as a primary criterion: that pattern fits albic / bleached horizons of Podzols just as well as truly reduced gleyic horizons. v0.3 will add reductimorphic / oxidimorphic feature discrimination once we model field-described mottle properties. v0.9.72 adds the designation-suffix path (opt-in).

Value

A DiagnosticResult.

v0.9.72 designation morphological inference (opt-in)

Field-described Brazilian Gleissolos profiles (e.g.\ the Embrapa Redape curated dataset) routinely encode gleyic properties via the designation suffix g (e.g.\ Cg, Cg1, Cgn, Apg) plus low-chroma Munsell colours (chroma \<= 2), without recording redoximorphic_features_pct as a numeric percent. The strict canonical test then returns NA on every horizon and Gleissolos cascade to other Orders.

With options(soilKey.gleyic_designation_inference = TRUE) the function accepts a layer as gleyic when:

1. the canonical redoximorphic_features_pct test is NA for that layer, AND
2. the designation matches [A-Z]+g[0-9a-z]? (a horizon name with a g suffix in the master letter sequence, e.g.\ Cg, Bg2, Apg, Cgn), AND
3. the layer has munsell_chroma_moist <= 2 (low-chroma reduced colour) when Munsell is recorded; if Munsell is missing on the layer the suffix alone is sufficient (designation suffix is the most direct signal of pedologist field judgment).

This is conservative: the suffix g is a master-letter modifier in the FAO/Embrapa horizon nomenclature that explicitly means "gleyic-affected" – the curator already made the call. Default is FALSE (canonical behaviour preserved).

References

IUSS Working Group WRB (2022), Chapter 3, Gleyic properties.

`gleysol` *Gleysol RSG gate (WRB 2022 Ch 4, p 103)*

Description

WRB-canonical (multi-path):

1. Layer \>= 25 cm starting \<= 40 cm with gleyic properties throughout AND reducing conditions in some parts of every sublayer; OR
2. Mollic/umbric > 40 cm thick with reducing conditions some parts of every sublayer 40 cm below mineral surface to lower limit, AND directly underneath a layer \>= 10 cm with lower limit \>= 65 cm having gleyic properties + reducing conditions; OR
3. Permanent saturation by water \<= 40 cm.

v0.3.4 enforces path 1 (the dominant path) and path 3 via designation (W / saturated marker). Path 2 is deferred (requires a depth-of- saturation column that's not standard).

Usage

```
gleysol(pedon)
```

Arguments

pedon	A PedonRecord.

`glossic_subgroup_usda` *Glossic Subgroup helper (Glossaqualfs, Glossocryalfs, Glossudalfs) Pass when interfingering of albic materials into argillic horizon is detected. v0.8 proxy: albic + argillic + lateral chroma <= 2 on argillic boundary.*

Description

Glossic Subgroup helper (Glossaqualfs, Glossocryalfs, Glossudalfs) Pass when interfingering of albic materials into argillic horizon is detected. v0.8 proxy: albic + argillic + lateral chroma <= 2 on argillic boundary.

Usage

```
glossic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

grapes-or-or-grapes *Default-value-for-NULL operator*

Description

Returns the left-hand side if it is non-NULL, otherwise the right-hand side. Re-exported so that downstream code can use the same idiom soilKey itself uses internally.

Usage

```
a %||% b
```

Arguments

a	The candidate value.
b	The fallback used when a is NULL.

Value

Either a or b.

grossarenic_subgroup_usda *Grossarenic Subgroup helper: sandy throughout, spodic >= 125 cm.*

Description

Grossarenic Subgroup helper: sandy throughout, spodic >= 125 cm.

Usage

```
grossarenic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

GSM_DEPTHS — *Default GlobalSoilMap depth intervals (cm)*

Description

GSM standard per Arrouays et al. (2014) "GlobalSoilMap: Toward a fine-resolution global grid of soil properties". Boundaries: 0-5, 5-15, 15-30, 30-60, 60-100, 100-200 cm.

Usage

```
GSM_DEPTHS
```

Format

An object of class `numeric` of length 7.

gypsic — *Gypsic horizon (WRB 2022)*

Description

Tests whether any horizon meets the gypsic horizon criteria. The gypsic horizon is a horizon of secondary gypsum accumulation, diagnostic for Gypsisols.

Usage

```
gypsic(pedon, min_thickness = 15, min_gypsum_pct = 5)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness in cm (default 15).
`min_gypsum_pct`	Minimum gypsum percent in fine earth (default 5).

Details

Sub-tests called:

- `test_caso4_concentration` – gypsum >= 5%.
- `test_minimum_thickness` – thickness >= 15 cm.

v0.2 limitations: the WRB rule that gypsum content must exceed the underlying horizon by 1% (absolute) is not enforced. Petrogypsic (cemented) horizons are not yet detected. Both deferred to v0.3.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022). *World Reference Base for Soil Resources*, 4th edition. International Union of Soil Sciences, Vienna. Chapter 3 – Gypsic horizon.

`gypsic_horizon_usda` *Gypsic horizon (USDA, delegates to WRB gypsic).*

Description

Gypsic horizon (USDA, delegates to WRB gypsic).

Usage

```
gypsic_horizon_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`gypsic_subgroup_usda` *Gypsic Subgroup helper – delegates to gypsic_horizon_usda.*

Description

Gypsic Subgroup helper – delegates to gypsic_horizon_usda.

Usage

```
gypsic_subgroup_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`gypsiric_material` *Gypsiric material (WRB 2022 Ch 3.3.7): \>= 5% gypsum that is primary (not secondary). Without a "secondary fraction" schema column, v0.3.3 treats any layer with caso4_pct >= 5 as gypsiric unless it explicitly carries gypsic-horizon designation.*

Description

Gypsiric material (WRB 2022 Ch 3.3.7): \>= 5% gypsum that is primary (not secondary). Without a "secondary fraction" schema column, v0.3.3 treats any layer with caso4_pct >= 5 as gypsiric unless it explicitly carries gypsic-horizon designation.

Usage

```
gypsiric_material(pedon, min_caso4_pct = 5)
```

Arguments

`pedon`	A `PedonRecord`.
`min_caso4_pct`	Numeric threshold or option (see Details).

`halaquept_qualifying_usda` *Halic helper for Halaquepts Pass when EC >= 8 dS/m within 100 cm.*

Description

Halic helper for Halaquepts Pass when EC >= 8 dS/m within 100 cm.

Usage

```
halaquept_qualifying_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

halic_subgroup_usda *Halic Subgroup helper (Haplosaprists)*

Description

Pass when EC >= 30 dS/m through a 30+ cm layer for 6+ months (KST 13ed, Ch 10). v0.8 proxy: any layer with ec_dS_m >= 30.

Usage

```
halic_subgroup_usda(pedon, min_ec = 30, min_thickness_cm = 30)
```

Arguments

pedon	A PedonRecord.
min_ec	Default 30.
min_thickness_cm	Default 30.

Value

A DiagnosticResult.

harmonize_to_gsm *Harmonise pedons to GlobalSoilMap depth intervals*

Description

Runs `mpspline2::mpspline_tidy()` on each requested numeric horizon attribute, producing a new PedonRecord per input pedon whose horizons table covers the canonical GSM intervals (GSM_DEPTHS). Categorical attributes (designation, Munsell hue) are propagated by mode-over-depth-overlap.

Usage

```
harmonize_to_gsm(
  pedons,
  attributes = c("clay_pct", "silt_pct", "sand_pct", "ph_h2o", "oc_pct", "cec_cmol",
    "base_saturation_pct", "munsell_value_moist", "munsell_chroma_moist",
    "redoximorphic_features_pct"),
  depths = GSM_DEPTHS,
  lam = 0.1,
  verbose = TRUE
)
```

Arguments

pedons	A list of PedonRecord objects.
attributes	Character vector of numeric horizon column names to harmonise. Default covers the chemistry / texture / Munsell numeric columns the soilKey diagnostics use.
depths	Numeric vector of GSM depth boundaries (n+1 values for n intervals). Default GSM_DEPTHS.
lam	Smoothing parameter for the spline (default 0.1, per Bishop et al. 1999 recommendation).
verbose	If TRUE (default), emits cli progress.

Value

A list of new PedonRecord objects with harmonised horizons.

Why mass-preserving

The Bishop et al. (1999) spline conserves the integral of the attribute over depth: if the original pedon has 30 g/kg OC over 0-15 cm, the harmonised pedon will report 30 g/kg integrated over 0-15 cm (split between 0-5 and 5-15 in proportion to the spline-implied gradient). This is a critical property for benchmark integrity: simple linear interpolation does not preserve mass and biases means upward / downward systematically.

Categorical handling

`designation` and `munsell_hue_moist` (and other character columns in the horizon schema) cannot be splined. Instead, for each target GSM interval, we pick the modal value weighted by the depth-overlap fraction with the input horizons. Ties broken by uppermost-input-horizon precedence.

References

Bishop, T.F.A., McBratney, A.B., Laslett, G.M. (1999). "Modelling soil attribute depth functions with equal-area quadratic smoothing splines." *Geoderma* 91: 27-45.

Arrouays, D. et al. (2014). "GlobalSoilMap: Toward a fine-resolution global grid of soil properties." *Advances in Agronomy* 125: 93-134.

See Also

`mpspline2::mpspline_tidy`, GSM_DEPTHS.

hemico — *Material organico hemico (SiBCS Cap 14)*

Description

Material organico em decomposicao intermediaria: 17-40% de fibras esfregadas OU indice de von Post H5-H6. Discrimina Organossolos Hemicos no 3o nivel.

Usage

```
hemico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 14 (Organossolos), pp 224-226.

hemic_subgroup_usda — *Hemic Subgroup helper*

Description

Hemic Subgroup helper

Usage

```
hemic_subgroup_usda(pedon, max_top_cm = 130)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`histel_qualifying_usda` *Histels Suborder qualifier (USDA, KST 13ed)*

Description

Pass when a Gelisol has organic soil materials that:

- Total >= 40 cm cumulative thickness within 0-50 cm; OR
- Comprise >= 80% (by volume) of 0-50 cm.

KST 13ed, Ch 9, p 189 (item AA in Key to Suborders).

Usage

```
histel_qualifying_usda(pedon, min_thickness_cm = 40, max_top_cm = 50)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness_cm`	Default 40.
`max_top_cm`	Default 50.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 9, p 189.

`histic_epipedon_usda` *Histic epipedon (USDA Soil Taxonomy, 13th edition)*

Description

A surface horizon (or layers within 40 cm of the surface) that is periodically saturated with water and has sufficiently high organic carbon to be considered organic soil material. Diagnostic for the Histosols order, the Histels suborder of Gelisols, and the Hist- modifier in many other taxa.

Usage

```
histic_epipedon_usda(
  pedon,
  min_oc_pct = 12,
  min_thickness_cm = 20,
  min_ap_oc_pct = 8
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_oc_pct`	Minimum organic carbon percent for organic soil material (default 12; equivalent to ~20% organic matter per KST conversion factor 0.58).
`min_thickness_cm`	Minimum thickness (default 20 cm).
`min_ap_oc_pct`	Minimum OC for the Ap-horizon shortcut (default 8 percent).

Details

KST 13ed required characteristics (Ch. 3, pp 13-15):

- Saturated 30+ days/year (or artificially drained); AND
- Organic soil material that is either:
  - 20-60 cm thick AND (Sphagnum >= 75 percent OR bulk_density < 0.1 g/cm3); OR
  - 20-40 cm thick (general); OR
- OR Ap horizon mixed to 25 cm with OC >= 8 percent by weight.

Implementation notes (v0.8.x):

- Saturation is detected via a horizon designation starting with H (per KST notation) or via the WRB `horizonte_glei` as fallback when redoximorphic features are present.
- Sphagnum content uses the WRB `fiber_content_rubbed_pct` column (>= 75 means very fibrous); refinement to a true Sphagnum-specific column is deferred.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022). *Keys to Soil Taxonomy*, 13th edition, USDA-NRCS, Washington DC. Ch. 3, pp. 13-15.

histic_horizon *Histic horizon (WRB 2022)*

Description

A surface (or near-surface, after drainage) horizon of organic material; diagnostic of Histosols. Two alternative qualifying paths per WRB 2022:

- **Contiguous**: a single layer of organic material (OC % >= `min_oc`) reaching the surface and at least `min_thickness` cm thick (default 10 cm).
- **Cumulative**: organic material totalling `cumulative_min_cm` cm (default 40) within the upper `cumulative_max_depth_cm` (default 80). Relevant for folic / mossy Histosols on slopes.

Either path qualifies. The "after drainage" qualifier (recently drained organic soils) is treated as implicit since the same OC and thickness criteria apply.

Usage

```
histic_horizon(
  pedon,
  min_thickness = 10,
  min_oc = 12,
  surface_top_cm = 0,
  cumulative_min_cm = 40,
  cumulative_max_depth_cm = 80
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness (cm) for the contiguous path (default 10).
`min_oc`	Minimum organic carbon % (default 12, WRB 2022; equivalent to `>= 20%` organic matter).
`surface_top_cm`	Maximum top depth (cm) for a layer to be considered "surface-related" in the contiguous path (default 0).
`cumulative_min_cm`	Minimum cumulative thickness (cm) for the cumulative path (default 40).
`cumulative_max_depth_cm`	Depth window (cm) for the cumulative path (default 80).

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 3, Histic horizon and organic material.

histic_subgroup_usda *Histic Subgroup helper (in Spodosols, Aquods) Pass when histic_epipedon_usda passes.*

Description

Histic Subgroup helper (in Spodosols, Aquods) Pass when histic_epipedon_usda passes.

Usage

```
histic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

histosol_qualifying_usda *Histosols Order qualifier (USDA, KST 13ed, Ch 2, p 7)*

Description

Organic soils not meeting the Gelisols requirements (no permafrost within 100 cm). The KST defines Histosols as soils with organic soil materials that meet specific thickness/depth criteria (Ch 2, pp 7-9; see also Ch 3 organic soil materials).

Usage

```
histosol_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation: pass when cumulative organic-layer thickness (designation H or O) within 0-100 cm >= 40 cm AND no permafrost within 100 cm.

Value

A DiagnosticResult.

References

Soil Survey Staff (2022), KST 13ed, Ch. 2, pp 7-9.

`histosol_usda` *Histosols (USDA Cap 10): organic materials >= 40 cm in 0-100. Refined v0.8.4 – now uses histosol_qualifying_usda (40 cm threshold) instead of WRB histic_horizon (10 cm).*

Description

Histosols (USDA Cap 10): organic materials >= 40 cm in 0-100. Refined v0.8.4 – now uses histosol_qualifying_usda (40 cm threshold) instead of WRB histic_horizon (10 cm).

Usage

```
histosol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`horizonte_A_antropico` *Horizonte A antropico (SiBCS) (SiBCS Cap 2, p 53)*

Description

Antropic surface formed by long human use; \>= 20 cm + P Mehlich-1 \>= 30 mg/kg + evidencias antropogenicas. Reuso de hortic (WRB) com criterios SiBCS-specific.

Usage

```
horizonte_A_antropico(pedon)
```

Arguments

pedon	A PedonRecord.

`horizonte_A_chernozemico` *Horizonte A chernozemico (SiBCS Cap 2, p 50-51)*

Description

Horizonte mineral superficial relativamente espesso, escuro, com alta saturacao por bases (V \>= 65%), OC \>= 6 g/kg, estrutura desenvolvida e espessura conforme criterio.

Usage

```
horizonte_A_chernozemico(
  pedon,
  min_oc_g_kg = 6,
  min_v_pct = 65,
  max_value_moist = 3,
  max_chroma_moist = 3,
  max_value_dry = 5,
  min_thickness_cm = 18
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_oc_g_kg`	Numeric threshold or option (see Details).
`min_v_pct`	Numeric threshold or option (see Details).
`max_value_moist`	Numeric threshold or option (see Details).
`max_chroma_moist`	Numeric threshold or option (see Details).
`max_value_dry`	Numeric threshold or option (see Details).
`min_thickness_cm`	Numeric threshold or option (see Details).

`horizonte_A_fraco` *Horizonte A fraco (SiBCS Cap 2, p 53): cor clara + estrutura grao simples/macica + OC < 6 g/kg; OR espessura < 5 cm.*

Description

Horizonte A fraco (SiBCS Cap 2, p 53): cor clara + estrutura grao simples/macica + OC < 6 g/kg; OR espessura < 5 cm.

Usage

```
horizonte_A_fraco(pedon)
```

Arguments

pedon	A PedonRecord.

---

horizonte_A_humico *Horizonte A humico (SiBCS Cap 2, p 51-52)*

Description

Horizonte A com cor moderadamente escura (value/chroma <= 4), V < 65%, e C organico total >= 60 + 0.1 * argila_media (g/kg). Espessura \>= a do A chernozemico.

Usage

```
horizonte_A_humico(pedon, min_v_pct_max = 65, min_thickness_cm = 18)
```

Arguments

pedon	A PedonRecord.
min_v_pct_max	Numeric threshold or option (see Details).
min_thickness_cm	Numeric threshold or option (see Details).

---

horizonte_A_moderado *Horizonte A moderado (SiBCS Cap 2, p 53-54): catch-all. Returns TRUE quando o solo tem horizonte superficial mas nao se enquadra nas demais classes diagnosticas superficiais.*

Description

Horizonte A moderado (SiBCS Cap 2, p 53-54): catch-all. Returns TRUE quando o solo tem horizonte superficial mas nao se enquadra nas demais classes diagnosticas superficiais.

Usage

```
horizonte_A_moderado(pedon)
```

Arguments

pedon	A PedonRecord.

horizonte_A_proeminente *Horizonte A proeminente (SiBCS Cap 2, p 52-53)*

Description

Como A chernozemico (cor escura, OC >= 6 g/kg) **mas com V < 65%**.

Usage

```
horizonte_A_proeminente(pedon)
```

Arguments

pedon	A PedonRecord.

horizonte_calcico *Horizonte calcico (SiBCS Cap 2, p 71-72; v0.7)*

Description

Reuso direto de calcic (WRB Ch 3.1.5) – criterios identicos: 150 g/kg CaCO3 + 50 g/kg a mais que sub-jacente + espessura \>= 15 cm.

Usage

```
horizonte_calcico(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Reserved for future arguments.

horizonte_concrecionario *Horizonte concrecionario (SiBCS Cap 2, p 68-69; v0.7)*

Description

\>= 50% volume material grosso (predominio petroplintita) numa matriz, espessura \>= 30 cm. Designation Ac/Ec/Bc/Cc.

Usage

```
horizonte_concrecionario(
  pedon,
  min_petroplinthite_pct = 50,
  min_thickness = 30
)
```

Arguments

pedon	A PedonRecord.
min_petroplinthite_pct	Numeric threshold or option (see Details).
min_thickness	Numeric threshold or option (see Details).

horizonte_E_albico *Horizonte E albico (SiBCS Cap 2, p 66-67; v0.7)*

Description

Reuso de albic (WRB Ch 3.1) com criterios identicos.

Usage

```
horizonte_E_albico(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Reserved for future arguments.

horizonte_glei *Horizonte glei (SiBCS Cap 2, p 69-71; v0.7)*

Description

Subsuperficial (ou eventualmente superficial) com cores neutras / azuladas / esverdeadas devido a reducao de Fe; espessura \>= 15 cm. Reuso de gleyic_properties (WRB) com nomenclatura SiBCS.

Usage

```
horizonte_glei(pedon, min_thickness = 15)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).

horizonte_histico *Horizonte histico (SiBCS Cap 2, p 49-50)*

Description

Horizonte O ou H de coloracao preta/cinza muito escura/brunada, \>= 80 g/kg (8%) C organico, com:

- espessura \>= 20 cm; OR
- espessura \>= 40 cm se \>= 75% volume tecido vegetal; OR
- espessura \>= 10 cm sobre contato litico/fragmentario OR camada com \>= 90% material > 2 mm.

Usage

```
horizonte_histico(pedon, min_oc_g_kg = 80)
```

Arguments

pedon	A PedonRecord.
min_oc_g_kg	Numeric threshold or option (see Details).

`horizonte_litoplintico` *Horizonte litoplintico (SiBCS Cap 2, p 69; v0.7)*

Description

Petroplintita continua (ironstone). Reuso de `petroplinthic` (WRB), espessura \>= 10 cm.

Usage

```
horizonte_litoplintico(pedon, min_thickness = 10)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).

`horizonte_petrocalcico` *Horizonte petrocalcico (SiBCS Cap 2, p 72; v0.7)*

Description

Reuso de `petrocalcic` (WRB v0.3.3).

Usage

```
horizonte_petrocalcico(pedon, ...)
```

Arguments

`pedon`	A `PedonRecord`.
`...`	Reserved for future arguments.

horizonte_plintico *Horizonte plintico (SiBCS Cap 2, p 67-68; v0.7)*

Description

Plintita \>= 15% volume, espessura \>= 15 cm. Tem precedencia sobre B textural, latossolico, nitico, B incipiente, planico (sem carater sodico), e glei. Reuso de `plinthic` (WRB).

Usage

```
horizonte_plintico(pedon, min_plinthite_pct = 15, min_thickness = 15)
```

Arguments

`pedon`	A `PedonRecord`.
`min_plinthite_pct`	Numeric threshold or option (see Details).
`min_thickness`	Numeric threshold or option (see Details).

horizonte_sulfurico *Horizonte sulfurico (SiBCS Cap 2, p 72-73; v0.7)*

Description

Reuso de `thionic` (WRB v0.3.3): pH \<= 3.5 + sulfidic material + espessura \>= 15 cm.

Usage

```
horizonte_sulfurico(pedon, ...)
```

Arguments

`pedon`	A `PedonRecord`.
`...`	Reserved for future arguments.

horizonte_vertico — *Horizonte vertico (SiBCS Cap 2, p 73; v0.7)*

Description

Reuso de vertic_horizon (WRB Ch 3.1, v0.3.3) com criterios essencialmente identicos: clay \>= 30%, slickensides, fendas \>= 1 cm, espessura \>= 20 cm. v0.7 SiBCS additional gate: COLE \>= 0.06 (proxy via shrink-swell).

Usage

```
horizonte_vertico(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Reserved for future arguments.

hortic — *Hortic horizon (WRB 2022): garden / kitchen-midden topsoil. Diagnostic criteria: thickness \>= 20 cm, dark colour (mollic-like), high P (Mehlich-3 P >= 100 mg/kg or P2O5_1pct_citric >= 175 mg/kg), high SOC.*

Description

Hortic horizon (WRB 2022): garden / kitchen-midden topsoil. Diagnostic criteria: thickness \>= 20 cm, dark colour (mollic-like), high P (Mehlich-3 P >= 100 mg/kg or P2O5_1pct_citric >= 175 mg/kg), high SOC.

Usage

```
hortic(pedon, min_thickness = 20, min_oc = 1, min_p_mehlich3 = 100)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
min_oc	Numeric threshold or option (see Details).
min_p_mehlich3	Numeric threshold or option (see Details).

humic_andisol_usda *Humic Andisols Subgroup helper Pass when mollic OR umbric epipedon present.*

Description

Humic Andisols Subgroup helper Pass when mollic OR umbric epipedon present.

Usage

```
humic_andisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

humic_inceptisol_usda *Humic Inceptisol Suborder helper (Hum*) Pass when umbric or mollic epipedon present + thick (>= 25 cm).*

Description

Humic Inceptisol Suborder helper (Hum*) Pass when umbric or mollic epipedon present + thick (>= 25 cm).

Usage

```
humic_inceptisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

humic_oxisol_usda

*Humic-Oxisol Subgroup helper Pass when cumulative organic carbon mass is >= 16 kg/m2 between surface and 100 cm (computed as SUM(OC% * bulk_density * dz)). v0.8 proxy: uses default bulk_density 1.0 g/cm3 if unavailable.*

Description

Humic-Oxisol Subgroup helper Pass when cumulative organic carbon mass is >= 16 kg/m2 between surface and 100 cm (computed as SUM(OC% * bulk_density * dz)). v0.8 proxy: uses default bulk_density 1.0 g/cm3 if unavailable.

Usage

```
humic_oxisol_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

humic_spodic_usda

Humic-spodic Suborder/GG check (>= 6% OC in 10+ cm of spodic)

Description

Humic-spodic Suborder/GG check (>= 6% OC in 10+ cm of spodic)

Usage

```
humic_spodic_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

humic_subgroup_usda — *Humic Subgroup helper (Humic Duricryods / Humic Placocryods) Pass when spodic horizon has >= 6% OC in 10+ cm.*

Description

Humic Subgroup helper (Humic Duricryods / Humic Placocryods) Pass when spodic horizon has >= 6% OC in 10+ cm.

Usage

```
humic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

humilluvic_subgroup_usda — *Humilluvic Subgroup helper (Luvihemists)*

Description

Pass when a horizon >= 2 cm thick has humilluvic material (humus translocated from above) >= 50% volume. v0.8 deferred (no specific column). Refinement to use a humilluvic_pct column or a designation marker is planned.

Usage

```
humilluvic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

`humult_qualifying_usda` *Humult Suborder qualifier (Ultisols with thick humus accumulation) Pass when 0.9% OC weighted average in 0-15 cm AND/OR organic carbon mass >= 12 kg/m2 in 0-100 cm (proxy via humic_oxisol_usda with lower threshold).*

Description

Humult Suborder qualifier (Ultisols with thick humus accumulation) Pass when 0.9% OC weighted average in 0-15 cm AND/OR organic carbon mass >= 12 kg/m2 in 0-100 cm (proxy via humic_oxisol_usda with lower threshold).

Usage

```
humult_qualifying_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`hydragric` *Hydragric horizon (WRB 2022): subsoil hydric horizon under anthraquic. v0.3.3 detects via designation pattern `Bg|Brg` immediately below an anthraquic-like topsoil.*

Description

Hydragric horizon (WRB 2022): subsoil hydric horizon under anthraquic. v0.3.3 detects via designation pattern `Bg|Brg` immediately below an anthraquic-like topsoil.

Usage

```
hydragric(pedon, min_thickness = 20)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).

hydraquent_qualifying_usda
Hydric Aquent helper (Hydraquents) Pass when surface 0-50 has high water content (n value high). v0.8 proxy: water_content_1500kpa >= 80% in surface.

Description

Hydric Aquent helper (Hydraquents) Pass when surface 0-50 has high water content (n value high). v0.8 proxy: water_content_1500kpa >= 80% in surface.

Usage

```
hydraquent_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

hydric_andisol_usda *Hydric (Andisols): 1500 kPa water retention >= 70% on undried samples throughout a 35+ cm layer within 100 cm.*

Description

Hydric (Andisols): 1500 kPa water retention >= 70% on undried samples throughout a 35+ cm layer within 100 cm.

Usage

```
hydric_andisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

hydric_subgroup_usda — *Hydric Subgroup helper (Histosols Cryofibrists / Sphagnofibrists / etc.)*

Description

Pass when there is a "layer of water" within the control section. Detected via designation containing "W" (water layer) or `layer_origin == "water"`.

Usage

```
hydric_subgroup_usda(pedon, max_top_cm = 130)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Default 130.

Value

A `DiagnosticResult`.

hypersulfidic_material — *Hypersulfidic material (WRB 2022 Ch 3.3.8): \>= 0.01% inorganic sulfidic S, pH \>= 4, capable of severe acidification on aerobic incubation.*

Description

Hypersulfidic material (WRB 2022 Ch 3.3.8): \>= 0.01% inorganic sulfidic S, pH \>= 4, capable of severe acidification on aerobic incubation.

Usage

```
hypersulfidic_material(pedon, min_s_pct = 0.01, min_pH = 4)
```

Arguments

`pedon`	A `PedonRecord`.
`min_s_pct`	Numeric threshold or option (see Details).
`min_pH`	Numeric threshold or option (see Details).

hyposulfidic_material *Hyposulfidic material (WRB 2022 Ch 3.3.9): same S and pH as hypersulfidic but does NOT consist of hypersulfidic (i.e. not capable of severe acidification). v0.3.3: returns sulfidic layers that don't meet hypersulfidic.*

Description

Hyposulfidic material (WRB 2022 Ch 3.3.9): same S and pH as hypersulfidic but does NOT consist of hypersulfidic (i.e. not capable of severe acidification). v0.3.3: returns sulfidic layers that don't meet hypersulfidic.

Usage

```
hyposulfidic_material(pedon, min_s_pct = 0.01, min_pH = 4)
```

Arguments

pedon	A PedonRecord.
min_s_pct	Numeric threshold or option (see Details).
min_pH	Numeric threshold or option (see Details).

inceptisol_qualifying_usda *Inceptisol Order qualifier Pass when a cambic horizon is present (no argillic, no spodic, no mollic, etc. – enforced by prior order exclusion).*

Description

Inceptisol Order qualifier Pass when a cambic horizon is present (no argillic, no spodic, no mollic, etc. – enforced by prior order exclusion).

Usage

```
inceptisol_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

inceptisol_usda	*Inceptisols (USDA Cap 11): cambic horizon (or several alternative subsurface diagnostics: folistic/histic/mollic with thin sub, salic, sodium-affected sub).*

Description

Inceptisols (USDA Cap 11): cambic horizon (or several alternative subsurface diagnostics: folistic/histic/mollic with thin sub, salic, sodium-affected sub).

Usage

```
inceptisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

inspect_bdsolos_csv	*Diagnostic inspection of a BDsolos CSV before loading*

Description

Reads the CSV header, attempts to map each column to the soilKey horizon schema via `.bdsolos_match_column`, and prints three sections:

Usage

```
inspect_bdsolos_csv(path, sep = NULL)
```

Arguments

path	Path to the CSV downloaded from BDsolos.
sep	Field separator (default ","; some BDsolos exports use ";" or tab).

Details

- **Mapped columns** – BDsolos name -> soilKey name
- **Unmapped columns** – columns the loader will ignore (review these before running `load_bdsolos_csv` to make sure no critical attribute is silently dropped)
- **Munsell coverage** – whether matiz / valor / croma are present in either umido or seco variants

Run this before `load_bdsolos_csv` on any new CSV from BDsolos, especially if the export schema looks unfamiliar (BDsolos has shipped multiple schema versions over the years).

Value

Invisibly, a list with `mapped`, `unmapped`, `munsell_present`, `taxon_column`.

irragric	*Irragric horizon (WRB 2022): topsoil thickened by irrigation deposits. v0.3.3: thickness >= 20 cm + sediment-derived structure proxied via designation* `Apk|Apg|Au`.

Description

Irragric horizon (WRB 2022): topsoil thickened by irrigation deposits. v0.3.3: thickness >= 20 cm + sediment-derived structure proxied via designation `Apk|Apg|Au`.

Usage

```
irragric(pedon, min_thickness = 20)
```

Arguments

pedon	A `PedonRecord`.
min_thickness	Numeric threshold or option (see Details).

kandic_horizon_usda	*Kandic horizon (USDA, KST 13ed Ch 3, p 45)*

Description

Subsurface horizon with low-activity clays (CEC <= 16 cmol/kg clay, ECEC <= 12) and clay increase. Implementation: delegates to argic with additional CEC/clay check.

Usage

```
kandic_horizon_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`kandic_oxisol_usda` *Kandic Suborder helper for Oxisols (Kandiperox/Kandiudox/Kandiustox) Delegates to kandic_horizon_usda.*

Description

Kandic Suborder helper for Oxisols (Kandiperox/Kandiudox/Kandiustox) Delegates to kandic_horizon_usda.

Usage

```
kandic_oxisol_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`kanhapl_qualifying_usda` *Kanhapl qualifying helper (Kanhapludults / Kanhaplustults / etc.) Pass when kandic horizon present BUT NOT meeting Pale criteria (i.e. younger / less developed kandic).*

Description

Kanhapl qualifying helper (Kanhapludults / Kanhaplustults / etc.) Pass when kandic horizon present BUT NOT meeting Pale criteria (i.e. younger / less developed kandic).

Usage

```
kanhapl_qualifying_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`kastanozem` *Kastanozem RSG diagnostic (WRB 2022)*

Description

Tests whether a profile satisfies the Kastanozem RSG criteria: a mollic horizon plus secondary carbonates plus NOT-Chernozem colour (chroma (moist) > 2 in the upper 20 cm).

Usage

```
kastanozem(pedon, max_chroma_upper = 2)
```

Arguments

`pedon`	A `PedonRecord`.
`max_chroma_upper`	Maximum moist chroma to qualify as Chernozem (default 2). Kastanozem requires the upper-20-cm chroma to EXCEED this value.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Kastanozems.

`kastanozem_strict` *Kastanozem RSG gate (strengthened, WRB 2022 Ch 4, p 112)*

Description

Same structure as `chernozem_strict` but using the mollic horizon (no chernic gate) and starting \<= 70 cm of mineral soil surface.

Usage

```
kastanozem_strict(pedon, min_bs = 50, max_top_cm = 70)
```

Arguments

`pedon`	A `PedonRecord`.
`min_bs`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).

kst13_canonical — *Keys to Soil Taxonomy 13th edition canonical reference*

Description

Convenience wrapper for `canonical_reference("ST_criteria_13th")`. Returns a nested list of 3,153 parsed Keys-to-Soil-Taxonomy clauses per chapter / page / key / taxon / code / clause / logic.

Usage

```
kst13_canonical(prefer_pkg = TRUE)
```

Arguments

`prefer_pkg`	If `TRUE` (default), prefer the installed SoilTaxonomy package over the vendored copy. Set to `FALSE` to force the vendored copy (e.g. for reproducibility of a specific soilKey release).

Details

Source: NCSS-tech `SoilTaxonomy` R package. Original: USDA-NRCS (2022). *Keys to Soil Taxonomy*, 13th edition.

kst13_codes — *Load the canonical KST 13ed code -> taxon-name lookup table*

Description

Returns the 3,153-row data.frame from `inst/rules/usda/canonical/2022_KST_codes.json`, vendored from NCSS-tech/SoilKnowledgeBase. Each row is a (code, name) pair.

Usage

```
kst13_codes()
```

Details

Code structure:

- Single letter (`"A"`-`"L"`): Soil Order (Gelisols, Histosols, ..., Entisols)
- Two letters (`"AB"`, `"AC"`, ...): Suborder
- Three letters: Great Group
- Four letters: Subgroup

Value

A data.frame with columns `code`, `name`.

See Also

`kst13_criteria`, `kst13_canonical`.

`kst13_criteria` *Load the canonical KST 13ed criteria for a single taxon code*

Description

Returns the parsed clause data.frame for one code (e.g. `"A"` for Gelisols, `"ABA"` for Histels.Folistels, etc.). Each row is one clause of the diagnostic text with `content`, `chapter`, `page` columns.

Usage

```
kst13_criteria(code)
```

Arguments

`code`	Character. Taxon code in the KST 13ed code system (e.g. `"A"` for Gelisols, `"ABCDA"` for the Lithic Folistels subgroup).

Details

For the full 3,153-element nested list (all codes), use `kst13_canonical` (which loads the SoilTaxonomy R-package RDA equivalent).

Value

A data.frame with the parsed clauses for that code, or `NULL` if the code is not present.

See Also

`kst13_codes`, `kst13_canonical`.

`lamellic_subgroup_usda` *Lamellic Subgroup helper (Spodosols Haplorthods)*

Description

Pass when 2+ lamellae (clay-rich bands < 7.5 cm thick) are present below the spodic horizon. v0.8: detected via designation containing "&" (lamella notation in KST) OR multiple thin clay-bumps in clay_pct.

Usage

```
lamellic_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

A `DiagnosticResult`.

`latossolo` *Latossolos (SiBCS Cap 4, p 113; conceito Cap 3, p 93-94)*

Description

Horizonte B latossolico imediatamente abaixo de qualquer tipo de A (exceto histico), dentro de 200 cm (ou 300 se A > 150 cm).

Usage

```
latossolo(pedon, max_top_cm = 200)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

latossolo_amarelo *Latossolos Amarelos (Cap 10): matiz \>= 7.5YR (mais amarelo).*

Description

Latossolos Amarelos (Cap 10): matiz \>= 7.5YR (mais amarelo).

Usage

```
latossolo_amarelo(pedon)
```

Arguments

pedon	A PedonRecord.

latossolo_bruno *Latossolos Brunos (Cap 10): matiz \>= 7.5YR + valor \<= 4 + croma \<= 5 (cores brunadas) OR caracter retratil.*

Description

Latossolos Brunos (Cap 10): matiz \>= 7.5YR + valor \<= 4 + croma \<= 5 (cores brunadas) OR caracter retratil.

Usage

```
latossolo_bruno(pedon)
```

Arguments

pedon	A PedonRecord.

latossolo_ki_kr *Ki/Kr para Latossolos (SiBCS Cap 10, p 173-176)*

Description

Diagnostico SiBCS estrito sobre o B latossolico: requer Ki $\leq$ max_ki em todos os horizontes B avaliados, e Kr $\leq$ max_kr quando Fe2O3 estiver disponivel. Sub-classes acricas (Latossolos Acricos) e acriferricas adicionalmente exigem `carater_acrico`.

Usage

```
latossolo_ki_kr(pedon, max_ki = 2.2, max_kr = 1.7)
```

Arguments

`pedon`	A `PedonRecord`.
`max_ki`	Ki limite superior (default 2.2 – limite kaolinitico SiBCS Cap 10).
`max_kr`	Kr limite superior (default 1.7).

Details

Quando os campos de ataque sulfurico (`sio2_sulfuric_pct`, `al2o3_sulfuric_pct`, `fe2o3_sulfuric_pct`) estao todos NA, o diagnostico retorna `passed = NA` com `missing` explicito.

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 10 (Latossolos), pp 173-176.

latossolo_vermelho *Latossolos Vermelhos (Cap 10): matiz \<= 2.5YR (mais vermelho).*

Description

Latossolos Vermelhos (Cap 10): matiz \<= 2.5YR (mais vermelho).

Usage

```
latossolo_vermelho(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

latossolo_vermelho_amarelo *Latossolos Vermelho-Amarelos (catch-all).*

Description

Latossolos Vermelho-Amarelos (catch-all).

Usage

```
latossolo_vermelho_amarelo(pedon)
```

Arguments

pedon	A PedonRecord.

leptic_features *Leptic features (WRB 2022)*

Description

Tests whether continuous rock or rock-like material occurs within max_depth cm of the surface. Two alternative paths qualify per WRB 2022:

1. **Designation**: a layer at depth <= max_depth with designation matching "^R" or "^Cr" (continuous rock or weathered rock-like substrate).
2. **Coarse fragments**: a layer at depth <= max_depth with coarse_fragments_pct >= min_coarse_pct (default 90% by volume), interpreted as rock-dominated even when not R / Cr-designated.

Either path qualifies.

Usage

```
leptic_features(pedon, max_depth = 25, min_coarse_pct = NULL, engine = NULL)
```

Arguments

pedon	A PedonRecord.
max_depth	Maximum depth (cm) at which continuous rock or rock-dominated material must appear (default 25).
min_coarse_pct	Minimum coarse-fragment percent for the coarse-fragments path (default 90 in soilkey engine, 50 in aqp engine; NULL picks a default per engine).

engine One of "soilkey" (default; strict 90\ cfvo threshold) or "aqp" (LUCAS-friendly relaxed 50\ requiring positive evidence of rock contact – v0.9.66 tightening). The thin-topsoil path fires only when a horizon ending within `max_depth` also satisfies *at least one* of: (a) designation contains "R" (e.g.\ AR, BR, Cr, R, Rk), (b) `coarse_fragments_pct >= 30` (gravelly), or (c) a deeper horizon is R/Cr-designated. Users with a strong external prior (e.g.\ a parent-material survey that documents rock < 25 cm but did not record it in the horizon table) can opt back into the original v0.9.65 loose behaviour with `options(soilKey.leptic_assume_rock_below = TRUE)`. `NULL` (the default) reads `getOption("soilKey.diagnostic_engine")`.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Leptosols.

`limnic_material` *Limnic material (WRB 2022 Ch 3.3.10): subaquatic deposits (coprogenous earth, diatomaceous earth, marl, gyttja). v0.3.3: detects via* `rock_origin %in% c("lacustrine", "marine")` *or designation pattern.*

Description

Limnic material (WRB 2022 Ch 3.3.10): subaquatic deposits (coprogenous earth, diatomaceous earth, marl, gyttja). v0.3.3: detects via `rock_origin %in% c("lacustrine", "marine")` or designation pattern.

Usage

```
limnic_material(pedon)
```

Arguments

pedon A `PedonRecord`.

limnic_usda — *Limnic Subgroup helper (Histels)*

Description

Pass when one or more limnic layers (coprogenous earth / diatomaceous earth / marl) with cumulative thickness >= 5 cm occur within the control section (KST 13ed, p 190).

Usage

```
limnic_usda(pedon, min_thickness_cm = 5, max_top_cm = 130)
```

Arguments

pedon	A PedonRecord.
min_thickness_cm	Default 5.
max_top_cm	Default 130 cm (control section).

Details

Implementation: detects designation containing 'L' (KST notation for limnic) OR `layer_origin == "lacustrine"`.

Value

A DiagnosticResult.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, p 45; Ch. 9 Hemistels / Sapristels.

limonic — *Limonic horizon (WRB 2022 Ch 3.1)*

Description

From Greek *leimon* = meadow. A subaqueous / wet-meadow horizon showing accumulation of secondary Fe/Mn (oxi)hydroxides from fluctuating redox cycles. Distinct from *limnic material* (Ch 3.3.10), which is the parent material; the limonic horizon is the *soil* horizon derived from such material plus subsequent pedogenesis.

Usage

```
limonic(pedon, min_thickness = 5, min_redox_pct = 5)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
min_redox_pct	Numeric threshold or option (see Details).

Details

v0.3.5 detection: redoximorphic_features_pct \>= 5 AND designation pattern `Bm` / `Bjm` / `m` as proxy for past meadow wetness.

`lithic_contact_usda` *Lithic contact within X cm of the surface (USDA Subgroup helper)*

Description

Pass when a horizon designation matches an R contact within `max_top_cm`. Default 50 cm (Subgroup-level depth bound). For Gelisols organic soil materials (Folistels), the depth is 50 cm; for Fibristels/Hemistels/Sapristels and other Gelisols, it is 100 cm (KST 13ed, p 46).

Usage

```
lithic_contact_usda(pedon, max_top_cm = 50)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Default 50 cm.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, p 45; Ch. 9 various Subgroups.

lithic_discontinuity *Lithic discontinuity (WRB 2022 Ch 3.2.7)*

Description

Significant abrupt change in parent material between two layers. v0.3.3 simplified: detects via large discontinuity in coarse_fragments_pct (>= 10pp absolute jump) OR rock_origin difference between consecutive layers.

Usage

```
lithic_discontinuity(pedon)
```

Arguments

pedon	A PedonRecord.

lixisol *Lixisol RSG diagnostic (WRB 2022)*

Description

argic + CEC < 24 cmol_c/kg clay + BS >= 50%.

Usage

```
lixisol(pedon, max_cec = 24, min_bs = 50)
```

Arguments

pedon	A PedonRecord.
max_cec	Maximum CEC per kg clay (default 24).
min_bs	Minimum base saturation % (default 50).

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 5, Lixisols.

load_afsp_pedons *Load Africa Soil Profiles (AfSP) v1.2 as PedonRecord objects*

Description

Reads the AfSP DBase tables shipped inside `AF-AfSP1.2.zip` (downloadable from https://files.isric.org/public/afsp/AF-AfSP1.2.zip) and converts each profile + its horizons to a soilKey PedonRecord. Filters to profiles with a populated WRB 2006 RSG code (i.e.\ classifiable; AfSP has ~7000 of these of the total 18,533).

Usage

```
load_afsp_pedons(
  afsp_dir,
  max_n = NULL,
  countries = NULL,
  wrb_codes = NULL,
  verbose = TRUE
)
```

Arguments

`afsp_dir`	Directory containing the extracted AfSP DBase tables (`AfSP012Qry_Profiles.dbf`, `AfSP012Qry_Layers.dbf`).
`max_n`	Optional integer; take a random sample of this size from the classifiable profiles.
`countries`	Optional character vector of ISO country codes to keep (e.g.\ `c("MW", "ET", "TZ")`).
`wrb_codes`	Optional character vector of WRB 2006 RSG codes to keep (e.g.\ `c("VR", "FR", "AC")`).
`verbose`	Print progress.

Value

A list of PedonRecord objects.

References

Leenaars, J. G. B., van Oostrum, A. J. M., & Ruiperez Gonzalez, M. (2014). Africa Soil Profiles Database, Version 1.2. ISRIC Report 2014/01. ISRIC – World Soil Information, Wageningen. Project page: https://isric.org/projects/africa-soil-profiles-database-afsp.

load_afsp_sample — *Load the bundled AfSP stratified sample (v0.9.77)*

Description

Returns a 130-profile snapshot from AfSP v1.2 stratified by WRB RSG (5 profiles per RSG x 26 RSGs), pre-built so users can run the African WRB benchmark offline without the 35 MB ZIP download.

Usage

```
load_afsp_sample()
```

Details

This is the African analogue of `load_wosis_stratified_sample` (global WoSIS) and `load_kssl_nasis_sample` (US KSSL+NASIS).

Value

A list with `pedons`, `pulled_on`, `source`, `filter`.

Reference

Leenaars, J. G. B., van Oostrum, A. J. M., & Ruiperez Gonzalez, M. (2014). Africa Soil Profiles Database, Version 1.2. ISRIC Report 2014/01.

load_bdsolos_csv — *Load a BDsolos CSV export as a list of PedonRecord objects*

Description

Reads the long-format BDsolos CSV (one row per horizon, with a profile-id key) and returns a list of `PedonRecord` objects. Auto-detects the column-name convention via `inspect_bdsolos_csv` and maps to the soilKey horizon schema. Texture (argila / silte / areia) is converted from g/kg to percent (BDsolos canonical unit).

Usage

```
load_bdsolos_csv(path, sep = NULL, verbose = TRUE)
```

Arguments

`path`	Path to the BDsolos CSV.
`sep`	Field separator. Default `","`; BDsolos sometimes exports with `";"` or tab – pass it explicitly.
`verbose`	If `TRUE` (default), prints a one-line summary.

Details

Profile-id columns are auto-detected: looks for any column whose normalised name matches `"id_perfil|profile_id|cod_`
falls back to the first column when none match.

Value

A list of `PedonRecord` objects. Each pedon has `site$id` from the profile-id column, the taxonomic reference (when present) at `site$reference_sibcs`, and one horizon row per CSV row matching the profile id.

See Also

`inspect_bdsolos_csv`, `download_bdsolos`.

`load_embrapa_pedons` *Load Embrapa dadosolos pedons with reference SiBCS classification*

Description

Reads the Embrapa BDsolos CSV export (or the dadosolos R package data frame, if present). Assembles a list of `PedonRecord` objects with the SiBCS classification attached as `pedon$site$reference_sibcs`.

Usage

```
load_embrapa_pedons(csv_path, head = NULL, verbose = TRUE)
```

Arguments

`csv_path`	Path to the BDsolos CSV (long format: one row per horizon, with a profile-id key and per-profile classification).
`head`	Optional integer for parser validation.
`verbose`	If `TRUE` (default), emits a summary.

Details

The dadosolos / BDsolos archive ships with ~5k profiles in PT-BR with full SiBCS classification, lab data, and horizon morphology – the primary validation set for Brazilian-context use. Available from `https://www.bdsolos.cnptia.embrapa.br/`.

Value

A list of `PedonRecord` objects.

load_febr_pedons — *Load the Embrapa FEBR superconjunto into a list of PedonRecords*

Description

Reads the FEBR `febr-superconjunto.txt` export (one row per camada / horizon, with the profile-level classification denormalised onto every row), groups rows by `(dataset_id, observacao_id)`, and returns a list of `PedonRecord` objects with all three reference taxa attached on `$site`: `reference_sibcs` (raw FEBR string, e.g. "LATOSSOLO VERMELHO"), `reference_usda`, `reference_wrb`.

Usage

```
load_febr_pedons(
  path,
  head = NULL,
  require_classification = c("sibcs", "any", "wrb", "usda"),
  verbose = TRUE
)
```

Arguments

`path`	Path to `febr-superconjunto.txt`.
`head`	Optional integer; if not `NULL`, return only the first `head` unique profiles after grouping.
`require_classification`	One of `c("any", "sibcs", "wrb","usda")`. Default `"sibcs"`: drop profiles whose chosen classification is NA. `"any"` keeps profiles with at least one of the three.
`verbose`	If `TRUE` (default), summarises the load.

Details

Drops profiles whose `taxon_sibcs` is NA (no usable reference). Drops camadas with no horizon-depth information (no `profund_sup` / `profund_inf`).

Value

A list of `PedonRecord` objects.

`load_kssl_nasis_sample`
Load the bundled KSSL + NASIS morphological-enriched sample (v0.9.75)

Description

Returns a 99-profile snapshot built by joining the NCSS Lab Data Mart (`ncss_labdata.gpkg`) with the companion NASIS Morphological sqlite (`NASIS_Morphological_*.sqlite`) via `load_kssl_pedons_with_nasis`. Pre-annotated with derived WRB Reference Soil Group via `usda_to_wrb_rsg`.

Usage

```
load_kssl_nasis_sample()
```

Details

Compared to `load_kssl_sample` (KSSL lab tables only), this sample carries the morphological evidence that several WRB diagnostic horizons need:

| Field | KSSL-only | KSSL + NASIS | |——-|————-:|—————-:| | munsell_hue_moist | 0 | munsell_value_moist | 0 | munsell_chroma_moist | 0 | munsell_hue_dry | 0 | structure_grade | 0 | structure_type | 0 | clay_films_amount | 0 | slickensides | 0

First-ever benchmark on this enriched sample (soilKey v0.9.75, full v0.9.69-72 fallback stack):

- Top-1 baseline: 19.1\ **+3.5pp lift purely from NASIS morphology**)
- Top-1 full stack: 20.6\
- Phaeozem: 1/33 -> 2/33 (Munsell-driven mollic detection)
- Podzol: 0/15 -> 1/15

Remaining ceiling driven by attributes neither dataset preserves: Solonetz needs Na/ESP, Vertisols need slickensides + cracks (NASIS records 1.7 on subsoil samples NASIS often lacks.

Value

A list with `pedons`, `pulled_on`, `source`, `join_helper`, `cross_walk`.

Reference

Beaudette, D., Skovlin, J., Roecker, S., Brown, A. (2024). aqp: Algorithms for Quantitative Pedology. R package version 2.x. https://github.com/ncss-tech/aqp.

Examples

```
s <- try(load_kssl_nasis_sample(), silent = TRUE)
if (!inherits(s, "try-error")) {
  length(s$pedons)
  # Munsell now populated (KSSL-only sample had 0%):
  mean(vapply(s$pedons,
              function(p) any(!is.na(p$horizons$munsell_hue_moist)),
              logical(1)))
}
```

`load_kssl_pedons` *Load NCSS / KSSL pedons with reference USDA Soil Taxonomy classification*

Description

Reads the KSSL pedon CSV export (typically named `NCSS_Pedon_Layer.csv` or similar) plus the lab-data CSV, joins on `pedon_key`, and assembles a list of `PedonRecord` objects. The published USDA Soil Taxonomy classification (from the `Series` or `Subgroup` field) is attached as `pedon$site$reference_usda`.

Usage

```
load_kssl_pedons(pedon_csv, layer_csv, head = NULL, verbose = TRUE)
```

Arguments

`pedon_csv`	Path to the pedon-level CSV (one row per profile, with site-level metadata + classification).
`layer_csv`	Path to the layer-level CSV (one row per horizon, with horizon properties).
`head`	Optional integer; if not `NULL`, returns only the first head pedons (useful for parser validation).
`verbose`	If `TRUE` (default), emits a summary of the load.

Details

KSSL is the de-facto standard for validating USDA Soil Taxonomy keys (~50k profiles, lab-grade analytical data, professional pedon descriptions). Get the export from `https://ncsslabdatamart.sc.egov.usda.gov/`.

Value

A list of `PedonRecord` objects.

`load_kssl_pedons_gpkg` *Load KSSL / NCSS pedons from the ncss_labdata GeoPackage*

Description

Reads the 'lab_combine_nasis_ncss' / 'lab_site' / 'lab_layer' / 'lab_chemical_properties' / 'lab_physical_properties' views from the NCSS Lab Data Mart GeoPackage and assembles a list of `PedonRecord` objects. Each pedon has its USDA Soil Taxonomy Order attached as `site$reference_usda`, normalised to match 'classify_usda()' output ("Mollisols", "Alfisols", ...).

Usage

```
load_kssl_pedons_gpkg(
  gpkg,
  head = NULL,
  require_b_horizon = TRUE,
  verbose = TRUE
)
```

Arguments

`gpkg`	Path to `ncss_labdata.gpkg`.
`head`	Optional integer; load only the first N classified pedons. Useful for parser validation.
`require_b_horizon`	If `TRUE` (default), drops pedons whose deepest horizon's bottom_cm < 30. Most non-Entisol Order gates need a B horizon.
`verbose`	If `TRUE` (default), emits progress messages.

Value

A list of `PedonRecord` objects.

`load_kssl_pedons_with_nasis`
Load KSSL pedons enriched with NASIS morphology

Description

Joins the NCSS Lab Data Mart GeoPackage with the NASIS Morphological SQLite to produce PedonRecord objects whose horizons table has BOTH lab chemistry + physics AND field morphology (Munsell, structure, clay films, slickensides, cracks). Required for the morphological-evidence diagnostics (`argic` clay-films, `vertic_horizon` slickensides, `mollic_epipedon_usda` Munsell, etc.) to fire on KSSL profiles – the lab gpkg alone has none of those.

Usage

```
load_kssl_pedons_with_nasis(
  gpkg,
  sqlite,
  head = NULL,
  require_b_horizon = TRUE,
  verbose = TRUE
)
```

Arguments

gpkg	Path to ncss_labdata.gpkg.
sqlite	Path to NASIS_Morphological_*.sqlite.
head	Optional integer; load only the first N classified pedons. Useful for parser validation / scaling.
require_b_horizon	If TRUE (default), drops pedons whose deepest horizon's bottom_cm < 30.
verbose	If TRUE (default), emits progress messages.

Value

A list of PedonRecord objects.

---

load_kssl_sample — *Load the bundled KSSL/NCSS lab-data sample (v0.9.74)*

Description

Returns a 100-profile snapshot from the NCSS Lab Data Mart (KSSL gpkg, head = 100) pre-annotated with derived WRB Reference Soil Group via usda_to_wrb_rsg.

Usage

```
load_kssl_sample()
```

Details

This is the bundled offline counterpart to load_kssl_pedons_gpkg – use this for tests and demos when the 5.5 GB gpkg is not available locally.

Each pedon has BOTH:

- site$reference_usda (Order, Suborder, Greatgroup, Subgroup) – the canonical KSSL classification.
- site$reference_wrb_from_usda – the derived WRB RSG via the IUSS WRB 2022 Annex 6 cross-walk.

First-ever KSSL WRB benchmark (soilKey v0.9.74, full v0.9.69-72 fallback stack):

- Top-1 accuracy: 20.1\
- Calcisol 69\
- Phaeozem / Kastanozem / Solonetz 0\ data not in KSSL lab tables (in companion NASIS).

Value

A list with pedons, pulled_on, source, cross_walk.

Reference

Beaudette, D., Skovlin, J., Roecker, S., Brown, A. (2024). aqp: Algorithms for Quantitative Pedology. R package version 2.x. https://github.com/ncss-tech/aqp.

Examples

```
s <- try(load_kssl_sample(), silent = TRUE)
if (!inherits(s, "try-error")) {
  length(s$pedons)
  table(vapply(s$pedons, function(p) p$site$reference_wrb_from_usda,
               character(1)))
}
```

---

load_lucas_pedons   *Load EU-LUCAS / ESDB pedons with reference WRB classification*

Description

Reads the EU-LUCAS topsoil dataset joined with the ESDB profile archive (the v3 release produced by JRC). Assembles a list of PedonRecord objects with the WRB Reference Soil Group attached as pedon$site$reference_wrb.

Usage

```
load_lucas_pedons(lucas_csv, head = NULL, verbose = TRUE)
```

Arguments

lucas_csv	Path to the LUCAS topsoil CSV.
head	Optional integer for parser validation.
verbose	If TRUE (default), emits a summary.

Details

LUCAS is harvested every 3-6 years on a regular grid; the ESDB classification is updated synchronously. ~28k profile cells with WRB labels in the 2015-2018 release.

Value

A list of `PedonRecord` objects.

`load_lucas_soil_2018` *Load the LUCAS Soil 2018 Topsoil release as a list of PedonRecord objects*

Description

Reads the canonical European Soil Data Centre (ESDAC) release of LUCAS Soil 2018 Topsoil chemistry as published in the JRC report (ESDAC dataset https://esdac.jrc.ec.europa.eu/content/lucas-2018-topsoil-data). The release ships ~18,984 European topsoil samples at 0-20 cm with pH (H2O and CaCl2), EC, OC, CaCO3, P, N, K and oxalate-extractable Al / Fe; a separate `BulkDensity_2018_final-2.csv` carries bulk density at 0-10 / 10-20 / 20-30 / 0-20 cm for ~6,272 of those points and is joined automatically when present.

Usage

```
load_lucas_soil_2018(
  path,
  attach_bulk_density = TRUE,
  countries = NULL,
  max_n = NULL,
  verbose = TRUE
)
```

Arguments

`path`	Folder containing `LUCAS-SOIL-2018.csv` (typically `<root>/LUCAS-SOIL-2018-data-report-readme-`
`attach_bulk_density`	If `TRUE` (default), joins the `BulkDensity_2018_final-2.csv` sister file on `POINTID` when present.
`countries`	Optional character vector of NUTS_0 codes (e.g. `c("ES", "FR")`) to filter pedons. Default `NULL` (all countries).
`max_n`	Optional integer cap on the number of pedons returned (after country filter). Useful for development.
`verbose`	If `TRUE` (default), prints a summary line.

Details

What's NOT in the release (and how to fill it):

- **Texture (clay / sand / silt)** – not in this CSV. Pass `benchmark_lucas_2018(..., fill_texture_from = "soilgrids")` to fill from ISRIC SoilGrids 250m via `lookup_soilgrids`.
- **Munsell colors** – not collected by LUCAS Soil 2018. If the user has Vis-NIR spectra (release separate ~83 GB), use `predict_munsell_from_spectra` (v0.9.47).

- **Vis-NIR spectra** – distributed separately by ESDAC. Once downloaded and attached to the pedon's `$spectra`, `predict_from_spectra` (v0.9.46) fills clay / sand / silt / pH / OC / CEC.
- **Taxonomic reference** – not in the LUCAS release; `benchmark_lucas_2018` attaches the canonical WRB Reference Soil Group via `lookup_esdb` (v0.9.44) at the pedon's coordinates.

Unit conversions applied (LUCAS -> soilKey schema):

- OC, N, CaCO3, Ox_Al, Ox_Fe: g/kg ->
- EC: mS/m -> dS/m (* 0.01)
- P, K: mg/kg unchanged
- pH: unitless

Special LUCAS string values `"< LOD"`, `"<LOD"`, empty cells and `"n.d."` / `"ND"` are converted to `NA` before numeric coercion.

Value

A list of `PedonRecord` objects (one per LUCAS point). Each pedon has a `site$id` matching the LUCAS `POINTID`, `site$lat` / `site$lon` in WGS84, and either one or two horizons (the second being 20-30 cm when the subsoil OC / CaCO3 columns are populated). Provenance entries from the loader use `source = "measured"`.

See Also

`benchmark_lucas_2018`, `lookup_esdb`, `lookup_soilgrids`.

Examples

```
path <- file.path(tempdir(), "LUCAS-SOIL-2018-v2")
if (dir.exists(path)) {
  pedons <- load_lucas_soil_2018(path, countries = c("ES", "PT"),
                                 max_n = 100)
  length(pedons)
  pedons[[1]]
}
```

`load_redape_pedons` *Load curated soil profiles from the Embrapa Redape GeoTab dataset*

Description

Reads the structured JSON files (one profile per file) published by Vaz et al. 2023 at the Embrapa Redape repository (DOI `10.48432/PYKKA7`) and converts each one to a soilKey `PedonRecord`.

Usage

```
load_redape_pedons(json_dir, max_n = NULL, verbose = TRUE)
```

Arguments

`json_dir`	Directory containing the GeoTab JSON files (or a character vector of file paths).
`max_n`	If non-`NULL`, take a random sample of this size.
`verbose`	Print progress (default `TRUE`).

Details

The dataset is unique in two ways:

- Every profile was hand-reviewed by experienced pedologists (the curation note and author list are preserved on each pedon site record), so it is suitable as a gold-standard benchmark.
- Unlike BDsolos, all profiles ship the full exchange complex (Ca, Mg, K, Na, Al *and H*), so `cec_cmol` (Valor T = S + H + Al) is computed directly without any fallback option.

Value

A list of `PedonRecord` objects.

Reference

Vaz, G. J., Silva Jr, A. F., & Silva Neto, L. de F. da (2023). Brazilian soil data for taxonomic classification. Redape, V1. doi:10.48432/PYKKA7.

See Also

`download_redape_dataset`, `benchmark_redape`.

---

load_rules *Load a soilKey rule set (YAML)*

Description

Load a soilKey rule set (YAML)

Usage

```
load_rules(system = c("wrb2022", "usda", "sibcs5"), package = "soilKey")
```

Arguments

`system`	One of `"wrb2022"` (full WRB 2022 key, v0.2 wires 16/32 RSGs), `"usda"` (USDA Soil Taxonomy, v0.2 scaffold with one delegating diagnostic), or `"sibcs5"` (SiBCS 5th edition, v0.2 scaffold with one delegating diagnostic).
`package`	Package owning the rule files (default `"soilKey"`).

Value

A parsed YAML list with elements `version`, `source`, and a system-specific taxa list (`rsgs`, `orders`, or `ordens`).

`load_wosis_sample` *Load the bundled WoSIS South-America sample*

Description

Returns a 40-profile snapshot of WoSIS GraphQL data pulled on 2026-05-03 with `continent = "South America"`. The data is a frozen artefact – do NOT use it for current paper-grade benchmarks (the WoSIS database is updated periodically; the bundled snapshot is for reproducible tests and offline development only).

Usage

```
load_wosis_sample()
```

Details

For up-to-date benchmarks, call `run_wosis_benchmark_graphql()` directly against the live ISRIC GraphQL endpoint.

Value

A list as described above.

Returned data

A list with elements:

- `profiles_raw` – the parsed GraphQL response (one element per profile; nested layer arrays).
- `pedons` – `PedonRecord` objects ready for classification (one per profile).
- `pulled_on` – `Date` of the snapshot.
- `endpoint`, `filter`, `n_pulled` – metadata.

Examples

```
sample <- try(load_wosis_sample(), silent = TRUE)
if (!inherits(sample, "try-error")) {
  length(sample$pedons)
  classify_wrb2022(sample$pedons[[1]])$rsg_or_order
}
```

load_wosis_stratified_sample
Load the bundled WoSIS stratified RSG-balanced sample (v0.9.73)

Description

Returns a 130-profile snapshot of WoSIS GraphQL data pulled on 2026-05-09 with **stratified sampling by WRB Reference Soil Group**: 5 profiles per RSG across 26 RSGs (Acrisol, Andosol, Arenosol, Calcisol, Cambisol, Chernozem, Cryosol, Ferralsol, Fluvisol, Gleysol, Gypsisol, Histosol, Kastanozem, Leptosol, Luvisol, Nitisol, Phaeozem, Planosol, Plinthosol, Podzol, Regosol, Solonchak, Solonetz, Stagnosol, Umbrisol, Vertisol).

Usage

```
load_wosis_stratified_sample()
```

Details

This is the recommended cache for global WRB benchmarking. Compared to `load_wosis_sample()` (40 SA-only profiles, mostly Solonetz and Phaeozem from Argentina), the stratified sample provides:

- Even coverage across the 26 most important RSGs.
- Richer analytical attributes – CEC available on 26 ECEC on 37 in the SA snapshot).
- Geographic diversity (Angola, Brazil, USA, China, Russia, South Africa, Indonesia, Argentina, etc.).

First-ever benchmark on this sample (soilKey v0.9.73, full v0.9.69-72 fallback stack):

- Overall top-1 accuracy: 16.2\
- Histosol 100\ from 20\ Cambisol 60\
- 18 RSGs at 0\ expose (Munsell colours, base saturation, sodium for Solonetz, slickensides for Vertisols, etc.). Documented data ceiling.

For the live API, call `run_wosis_benchmark_graphql()` or the `read_wosis_profiles_graphql(wrb_rsg = "...", n_max = N)` helper (small RSG-filtered queries are tractable; large unfiltered pulls time out as of 2026-05).

Value

A list with:

- `pedons`: list of 130 `PedonRecord` objects.
- `meta`: named integer vector of profiles per RSG.
- `pulled_on`: pull date.
- `endpoint`: ISRIC GraphQL endpoint URL.
- `filter`: pull strategy metadata.
- `n_pulled`: 130.

Reference

Batjes, N. H., Ribeiro, E., van Oostrum, A. (2020). Standardised soil profile data to support global mapping and modelling (WoSIS snapshot 2019). *Earth System Science Data*, 12, 299-320. doi:10.5194/essd122992020.

Examples

```
s <- try(load_wosis_stratified_sample(), silent = TRUE)
if (!inherits(s, "try-error")) {
  length(s$pedons)
  table(vapply(s$pedons, function(p) p$site$wosis_rsg, character(1)))
}
```

`lookup_esdb` *Look up an ESDB raster value at WGS84 coordinates*

Description

Loads the requested attribute raster, reprojects WGS84 lat/lon input to the raster's native CRS (typically LAEA Europe, EPSG:3035), and extracts the value(s). When a Value Attribute Table (‘.vat.dbf‘) is available, the integer raster value is decoded to its coded string (e.g. ‘21‘ -> ‘"LV"‘ -> Luvisol).

Usage

```
lookup_esdb(coords, attribute, raster_root, decode = TRUE)
```

Arguments

`coords`	A two-column matrix or data.frame with ‘lon‘ and ‘lat‘ (WGS84 decimal degrees) – in that order. A single `c(lon, lat)` vector is also accepted.
`attribute`	Name of the ESDB attribute folder, e.g. `"WRBLV1"` or `"WRBFU"`. See `available_esdb_attributes`.
`raster_root`	Path to the unpacked ESDB raster directory.
`decode`	If `TRUE` (default), decode the integer raster value to the VAT-coded string (e.g. `"21"` -> `"LV"`). If `FALSE`, return the raw integer.

Details

Coordinates outside the European raster footprint return ‘NA‘ silently (rather than erroring) so vectorised calls degrade gracefully.

Value

Character vector (decoded codes) or numeric vector (raw values) of the same length as `nrow(coords)`. `NA` for points outside the raster footprint.

See Also

available_esdb_attributes

Examples

```
root <- file.path(tempdir(), "ESDB-Raster-Library-1k-GeoTIFF-20240507")
if (dir.exists(root) && requireNamespace("terra", quietly = TRUE)) {
  # Single point: Wageningen, Netherlands (5.66 E, 51.97 N)
  lookup_esdb(c(5.66, 51.97), "WRBLV1", root)

  # Vector: Lisbon + Berlin + Helsinki
  coords <- rbind(c(-9.14, 38.72), c(13.40, 52.52), c(24.94, 60.17))
  lookup_esdb(coords, "WRBLV1", root)
}
```

---

lookup_mapbiomas_solos

Look up a MapBiomas Solos raster value at WGS84 coordinates

Description

MapBiomas Solos (Project MapBiomas, Brazil) distributes a national raster of SiBCS classes at 30 m, downloadable from https://mapbiomas.org/en/produtos. This helper mirrors the shape of lookup_esdb but is local-file only: pass the path of the unpacked GeoTIFF and the function reprojects the user's WGS84 lat/lon to the raster's native CRS, extracts the pixel and (optionally) decodes the integer class code via a user-supplied legend.

Usage

```
lookup_mapbiomas_solos(coords, raster_path, legend = NULL)
```

Arguments

coords	A 2-column matrix or data.frame with `lon`, `lat` (WGS84 decimal degrees), or a length-2 numeric vector for a single query.
raster_path	Path to the unpacked MapBiomas Solos GeoTIFF.
legend	Optional two-column data.frame (first column = numeric value, second = SiBCS class name). When provided, the integer raster value is decoded; when `NULL`, the raw integer is returned.

Details

MapBiomas does not bundle a '.vat.dbf'; the canonical legend is published as a CSV / dictionary on their website. Pass it via `legend` as a two-column data.frame (`value, class_name`) to enable decoding.

Value

Character vector of decoded class names (when `legend` is supplied) or numeric vector of raster values. Same length as `nrow(coords)`. `NA` for points outside the raster footprint.

See Also

`lookup_esdb`, `lookup_soilgrids`.

Examples

```
tif <- file.path(tempdir(), "mapbiomas_solos_collection2_2023.tif")
if (file.exists(tif)) {
  legend <- data.frame(
    value = c(1L, 2L, 3L, 4L, 5L, 6L, 7L, 8L, 9L, 10L, 11L, 12L, 13L),
    class_name = c("Latossolo Vermelho-Amarelo",
                   "Latossolo Amarelo",
                   "Argissolo Vermelho-Amarelo",
                   "Argissolo Amarelo",
                   "Neossolo Quartzarenico",
                   "Cambissolo Haplico",
                   "Espodossolo",
                   "Gleissolo",
                   "Nitossolo",
                   "Planossolo",
                   "Plintossolo",
                   "Vertisolo",
                   "Outros")
  )
  lookup_mapbiomas_solos(c(-43.0, -22.0), tif, legend)
}
```

`lookup_soilgrids` *Look up a SoilGrids 250m soil property at WGS84 coordinates*

Description

Reads ISRIC SoilGrids 250m (Hengl et al. 2017, 2021) directly from the ISRIC Cloud-Optimized GeoTIFF (COG) endpoint at https://files.isric.org/soilgrids/latest/data/ – no download required, only the pixel under each query coordinate is transferred over HTTPS.

Usage

```
lookup_soilgrids(
  coords,
  property = c("clay", "sand", "silt", "phh2o", "soc", "cec", "bdod", "nitrogen", "ocd",
    "ocs", "cfvo"),
  depth = c("0-5cm", "5-15cm", "15-30cm", "30-60cm", "60-100cm", "100-200cm"),
  quantile = c("mean", "Q0.05", "Q0.5", "Q0.95", "uncertainty"),
```

```
  baseurl = "https://files.isric.org/soilgrids/latest/data",
  raw = FALSE
)
```

Arguments

coords	A 2-column matrix or data.frame with `lon`, `lat` (WGS84 decimal degrees), or a length-2 numeric vector for a single query.
property	One of the SoilGrids 250m predicted properties: `"clay"`, `"sand"`, `"silt"`, `"phh2o"`, `"soc"`, `"cec"`, `"bdod"`, `"nitrogen"`, `"ocd"`, `"ocs"`, `"cfvo"`.
depth	Depth interval. One of `"0-5cm"`, `"5-15cm"`, `"15-30cm"`, `"30-60cm"`, `"60-100cm"`, `"100-200cm"`.
quantile	Output quantile. One of `"mean"` (default), `"Q0.05"`, `"Q0.5"`, `"Q0.95"`, `"uncertainty"`.
baseurl	Base URL of the SoilGrids COG endpoint. Default is the canonical ISRIC location; override only for a local mirror.
raw	If `TRUE`, returns the integer raster value without scaling. Default `FALSE` (returns the value in conventional units).

Details

SoilGrids stores integer rasters scaled per property; this helper applies the canonical conversion factor so the returned value is in conventional soil units (%, pH, g/kg, cmol(c)/kg, g/cm^3).

Value

Numeric vector of length `nrow(coords)`. `NA` outside the SoilGrids footprint or on network errors.

See Also

`lookup_esdb`, `lookup_mapbiomas_solos`.

Examples

```
if (requireNamespace("terra", quietly = TRUE)) {
  # Single point (needs internet -- guarded via try())
  try(lookup_soilgrids(c(-43.0, -22.0),
                       property = "phh2o",
                       depth = "0-5cm",
                       quantile = "mean"), silent = TRUE)

  # Vector + multiple properties
  coords <- rbind(c(-43.0, -22.0), c( -9.14, 38.72))
  try(lookup_soilgrids(coords, "clay",  "0-5cm", "mean"), silent = TRUE)
  try(lookup_soilgrids(coords, "phh2o", "0-5cm", "mean"), silent = TRUE)
}
```

luvisol *Luvisol RSG diagnostic (WRB 2022)*

Description

argic + CEC >= 24 cmol_c/kg clay + Al saturation < 50%.

Usage

```
luvisol(pedon, min_cec = 24, max_al_sat = 50)
```

Arguments

pedon	A PedonRecord.
min_cec	Minimum CEC per kg clay (default 24).
max_al_sat	Maximum Al saturation % (default 50).

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 5, Luvisols.

luvissolo *Luvissolos (SiBCS Cap 4, p 113; conceito Cap 3, p 95-96)*

Description

Horizonte B textural com argila ativ alta E saturacao por bases alta (V \>= 50%) na maior parte dos primeiros 100 cm do B (incl. BA), abaixo de A ou E.

Usage

```
luvissolo(pedon)
```

Arguments

pedon	A PedonRecord.

`luvissolo_cromico` *Luvissolos Cromicos (Cap 11): caracter cromico (cores fortes em B). Aplicado pela presenca de Munsell vermelho-amarelado em B com cromas altos.*

Description

Luvissolos Cromicos (Cap 11): caracter cromico (cores fortes em B). Aplicado pela presenca de Munsell vermelho-amarelado em B com cromas altos.

Usage

```
luvissolo_cromico(pedon)
```

Arguments

pedon	A PedonRecord.

`luvissolo_haplico` *Luvissolos Haplicos (catch-all).*

Description

Luvissolos Haplicos (catch-all).

Usage

```
luvissolo_haplico(pedon)
```

Arguments

pedon	A PedonRecord.

make_acrisol_canonical — *Build the canonical Acrisol fixture*

Description

Synthetic tropical-humid Acrisol on weathered gneiss: argic horizon at Bt1 with low-activity clay (CEC/clay ~ 17 cmol_c/kg clay) and low base saturation (BS ~ 25%). By construction:

- `argic`: PASSES on Bt1.
- `acrisol`: PASSES (CEC low, BS low).
- `lixisol`, `alisol`, `luvisol`: FAIL.
- Other diagnostics: FAIL.

Usage

```
make_acrisol_canonical()
```

Value

A `PedonRecord`.

make_alisol_canonical — *Build the canonical Alisol fixture*

Description

Synthetic humid-tropical Alisol on weathered shale: argic horizon at Bt1 with high-activity clay (CEC/clay ~ 34) AND high Al saturation (Al sat ~ 70%); the canonical "young weathering on a 2:1 clay parent that has not yet released enough Al into the precipitate-stabilised pool". By construction:

- `argic`: PASSES on Bt1.
- `alisol`: PASSES (CEC high, Al sat high).
- `acrisol`, `lixisol`, `luvisol`: FAIL.

Usage

```
make_alisol_canonical()
```

Value

A `PedonRecord`.

make_andosol_canonical

Build the canonical Andosol fixture

Description

Synthetic Andosol on volcanic tephra: very dark surface with low bulk density (0.7 g/cm^3) and high active Al + Fe (Al_ox + 0.5 * Fe_ox = 2.25%). By construction `andic_properties` passes.

Usage

```
make_andosol_canonical()
```

Value

A `PedonRecord`.

make_anthrosol_canonical

Build the canonical Anthrosol fixture

Description

Synthetic Anthrosol with a hortic horizon – a long-cultivated dark surface from sustained organic-matter additions (typical of centuries-old kitchen-garden / homegarden soils). By construction `anthric_horizons` passes via the designation pattern.

Usage

```
make_anthrosol_canonical()
```

Value

A `PedonRecord`.

`make_arenosol_canonical` *Build the canonical Arenosol fixture*

Description

Synthetic coastal-dune Arenosol: sandy throughout the upper 100 cm (silt + 2*clay « 30). By construction `arenic_texture` passes uniformly while every clay-dependent diagnostic fails.

Usage

```
make_arenosol_canonical()
```

Value

A `PedonRecord`.

`make_argissolo_canonical` *Perfil canonico de Argissolo (SiBCS 5a ed., Cap 5)*

Description

B textural com gradiente significativo, argila ativ baixa ou alta + V baixa. Catch-all final na chave – tipica do Brasil tropical.

Usage

```
make_argissolo_canonical()
```

`make_calcisol_canonical` *Build the canonical Calcisol fixture*

Description

Synthetic semi-arid Calcisol on calcareous loess: A horizon with modest secondary carbonate; a thick Bk1 with the diagnostic calcic horizon (35% CaCO3 over 40 cm); deepening accumulation in Bk2. By construction:

- `calcic`: PASSES on Bk1 and Bk2.
- `gypsic`, `salic`: FAIL.
- `argic`, `ferralic`, `mollic`: FAIL.

Usage

```
make_calcisol_canonical()
```

Value

A PedonRecord.

`make_cambisol_canonical`

Build the canonical Cambisol fixture

Description

Synthetic temperate-zone Cambisol on weathered colluvium: modest subsurface alteration in Bw without meeting argic clay-increase or ferralic CEC criteria. By construction:

- cambic: PASSES on Bw (thickness 35 cm, sandy clay loam, no argic / no ferralic).
- argic, ferralic, mollic, calcic, gypsic, salic: FAIL.

Usage

```
make_cambisol_canonical()
```

Value

A PedonRecord.

`make_cambissolo_canonical`

Perfil canonico de Cambissolo (SiBCS 5a ed., Cap 6)

Description

Reusa fixture WRB Cambisol – B incipiente sem ser plintico, vertico, planico, etc.

Usage

```
make_cambissolo_canonical()
```

`make_chernossolo_canonical`
Perfil canonico de Chernossolo (SiBCS 5a ed., Cap 7)

Description

Reusa fixture WRB Chernozem – A chernozemico + Bk com argila Ta + V alta. SiBCS strictos exigem (a) Bi/Bt + Ta + V alta, OR (b) calcico/petrocalcico/carbonatico + A chernozemico.

Usage

```
make_chernossolo_canonical()
```

`make_chernozem_canonical`
Build the canonical Chernozem fixture

Description

Synthetic Ukrainian / Russian steppe Chernozem on loess: thick dark Ah, granular structure, secondary carbonates accumulating in the Bk. By construction:

- `mollic`: PASSES on horizon Ah1 (moist value 2, chroma 1, dry value 3; SOC 4%; BS 89%; thickness 30 cm; strong granular structure).
- `argic`: FAILS (essentially no clay differentiation; ratios all close to 1).
- `ferralic`: FAILS (CEC/clay ~ 120 cmol_c/kg clay – high-activity 2:1 clay).

Usage

```
make_chernozem_canonical()
```

Value

A `PedonRecord`.

`make_cryosol_canonical` *Build the canonical Cryosol fixture*

Description

Synthetic Arctic Cryosol on weathered shale with permafrost at 50 cm: thawed A horizon over a frozen Bf horizon. By construction `cryic_conditions` passes via the designation pattern.

Usage

```
make_cryosol_canonical()
```

Value

A `PedonRecord`.

`make_durisol_canonical` *Build the canonical Durisol fixture*

Description

Synthetic semi-arid Durisol with a Si-cemented subsurface horizon (35% duripan nodules over 45 cm). By construction `duric_horizon` passes on Bdu.

Usage

```
make_durisol_canonical()
```

Value

A `PedonRecord`.

make_empty_horizons *Build an empty horizons data.table with the canonical schema*

Description

Build an empty horizons data.table with the canonical schema

Usage

```
make_empty_horizons(n = 0L)
```

Arguments

n	Number of rows (default 0).

Value

A `data.table` with all canonical horizon columns filled with NAs of the correct type.

Examples

```
h <- make_empty_horizons(3)
nrow(h)
```

make_espodossolo_canonical *Perfil canonico de Espodossolo (SiBCS 5a ed., Cap 8)*

Description

Reusa fixture WRB Podzol – B espodico imediatamente abaixo de E.

Usage

```
make_espodossolo_canonical()
```

make_ferralsol_canonical

Build the canonical Ferralsol fixture

Description

Synthetic but realistic Brazilian Latossolo Vermelho (Ferralsol per WRB 2022): deeply weathered, kaolinitic / oxidic, with the canonical "low-activity clay" signature. Diagnostic outcomes are deterministic by construction:

- `ferralic`: PASSES on horizons Bw1 and Bw2 (CEC/clay = 8.3 cmol_c/kg clay; ECEC/clay = 3.6 cmol_c/kg clay; texture sandy clay / clay; thickness >= 30 cm).
- `argic`: FAILS (gradual clay increase, all pairwise ratios < 1.2; absolute increment too small for the >= 40% rule).
- `mollic`: FAILS (chroma > 3, BS < 50%, A horizon < 20 cm thick).

Usage

```
make_ferralsol_canonical()
```

Value

A `PedonRecord`.

make_fluvisol_canonical

Build the canonical Fluvisol fixture

Description

Synthetic floodplain Fluvisol: stratified textures across consecutive C horizons, OC pattern non-monotone with depth (because C2 is more recently deposited, OC-richer than C1). By construction `fluvic_material` passes.

Usage

```
make_fluvisol_canonical()
```

Value

A `PedonRecord`.

`make_gleissolo_canonical` *Perfil canonico de Gleissolo (SiBCS 5a ed., Cap 9)*

Description

Reusa fixture WRB Gleysol – horizonte glei dentro de 50 cm.

Usage

```
make_gleissolo_canonical()
```

`make_gleysol_canonical` *Build the canonical Gleysol fixture*

Description

Synthetic Gleysol from a high-water-table floodplain: A with low chroma but no explicit redox features (so gleyic test is anchored on Bg); Bg with diagnostic redoximorphic features (35% by volume) within the upper 50 cm. By construction:

- `gleyic_properties`: PASSES on Bg.
- `argic`, `ferralic`, `mollic`, `cambic`, `plinthic`, `spodic`, `calcic`, `gypsic`, `salic`: FAIL.

Usage

```
make_gleysol_canonical()
```

Value

A `PedonRecord`.

make_gypsisol_canonical

Build the canonical Gypsisol fixture

Description

Synthetic Gypsisol on gypsiferous parent material: shallow A; gypsum accumulation rising sharply in the By1 horizon (35% gypsum over 50 cm) – the diagnostic gypsic horizon. By construction:

- `gypsic`: PASSES on By1 and By2.
- `calcic`, `salic`: FAIL.
- `argic`, `ferralic`, `mollic`: FAIL.

Usage

```
make_gypsisol_canonical()
```

Value

A `PedonRecord`.

make_histosol_canonical

Build the canonical Histosol fixture

Description

Synthetic boreal-mire Histosol: thick (50 cm) surface organic horizon with OC ~ 35%, low chroma, no exchangeable-base data reported (typical of histic profiles where laboratory chemistry on organic material is reported separately). By construction:

- `histic_horizon`: PASSES on Oa.
- Mineral horizons below; mollic / umbric NA (no BS reported).

Usage

```
make_histosol_canonical()
```

Value

A `PedonRecord`.

make_kastanozem_canonical

Build the canonical Kastanozem fixture

Description

Synthetic continental-semiarid Kastanozem on loess-like substrate: mollic surface (chroma 3, value 3) – dark enough for mollic but not dark enough for Chernozem (chroma 3 > 2 in the upper 20 cm); secondary carbonates accumulating in the Bk. By construction:

- mollic: PASSES.
- kastanozem: PASSES.
- chernozem, phaeozem: FAIL.

Usage

```
make_kastanozem_canonical()
```

Value

A PedonRecord.

make_latossolo_canonical

Perfil canonico de Latossolo (SiBCS 5a ed., Cap 10)

Description

Reusa fixture WRB Ferralsol – B latossolico imediatamente abaixo de A, sem horizonte argilico acima.

Usage

```
make_latossolo_canonical()
```

`make_leptosol_canonical` *Build the canonical Leptosol fixture*

Description

Synthetic mountain-slope Leptosol on metamorphic rock: a thin A (10 cm) directly over continuous rock. By construction:

- `leptic_features`: PASSES (R at 10 cm <= 25).
- Other diagnostics fail on thickness, missing data, or absent diagnostic features.

Usage

```
make_leptosol_canonical()
```

Value

A `PedonRecord`.

`make_lixisol_canonical` *Build the canonical Lixisol fixture*

Description

Synthetic Mediterranean / sub-tropical Lixisol on weathered calcareous parent material: argic horizon at Bt1 with low-activity clay (CEC/clay ~ 20) but high base saturation (BS ~ 70%) thanks to carbonate-buffered weathering. By construction:

- `argic`: PASSES on Bt1.
- `lixisol`: PASSES (CEC low, BS high).
- `acrisol`, `alisol`, `luvisol`: FAIL.

Usage

```
make_lixisol_canonical()
```

Value

A `PedonRecord`.

`make_luvisol_canonical`
Build the canonical Luvisol fixture

Description

Synthetic temperate-zone Luvisol on loess: clear textural differentiation, Bt with clay coatings, high base saturation, high- activity clay. By construction:

- `argic`: PASSES on horizon Bt1 (clay increase from E (18%) to Bt1 (35%) gives ratio 1.94 in the 15-40% band; thickness 25 cm; texture clay loam; no glossic features).
- `ferralic`: FAILS (CEC/clay ~ 45 cmol_c/kg clay in the Bt – well above the 16 cmol_c/kg threshold).
- `mollic`: FAILS (A horizon: moist value 4 > 3, thickness 10 cm < 20 cm).

Usage

```
make_luvisol_canonical()
```

Value

A `PedonRecord`.

`make_luvissolo_canonical`
Perfil canonico de Luvissolo (SiBCS 5a ed., Cap 11)

Description

Solo com B textural argila Ta + V alta. Tipico do semiarido com rocha basica.

Usage

```
make_luvissolo_canonical()
```

`make_neossolo_canonical`
Perfil canonico de Neossolo Litolico (SiBCS 5a ed., Cap 12)

Description

Solo raso sobre rocha continua dura. Sem horizonte B diagnostico.

Usage

```
make_neossolo_canonical()
```

make_nitisol_canonical
Build the canonical Nitisol fixture

Description

Synthetic East-African Nitisol on weathered basalt: clay-rich (>= 50%), Fe-rich (DCB ~ 6%), polyhedral structure with shiny ped surfaces. By construction `nitic_horizon` passes.

Usage

```
make_nitisol_canonical()
```

Value

A `PedonRecord`.

make_nitossolo_canonical
Perfil canonico de Nitossolo Vermelho (SiBCS 5a ed., Cap 13)

Description

Solo argiloso (>= 35% argila desde superficie) com B nitico (estrutura forte em blocos + cerosidade), gradiente textural baixo (B/A <= 1.5).

Usage

```
make_nitossolo_canonical()
```

make_organossolo_canonical
Perfil canonico de Organossolo (SiBCS 5a ed., Cap 14)

Description

Solo organico saturado, com horizonte H histico >= 60 cm e SOC alto. Tipico de varzea / brejo.

Usage

```
make_organossolo_canonical()
```

make_phaeozem_canonical

Build the canonical Phaeozem fixture

Description

Synthetic humid-temperate Phaeozem on non-calcareous loess: mollic (chroma 2, value 2-3) and high BS, but no secondary carbonates anywhere – typical of more leached / less-arid steppe-forest transition. By construction:

- `mollic`: PASSES.
- `phaeozem`: PASSES.
- `chernozem`, `kastanozem`: FAIL (no carbonates).

Usage

```
make_phaeozem_canonical()
```

Value

A `PedonRecord`.

make_planosol_canonical

Build the canonical Planosol fixture

Description

Synthetic temperate Planosol with abrupt textural change: sandy E (clay 12%) overlies a clay-rich Bt (35%) at 25 cm with an abrupt boundary. By construction `planic_features` passes.

Usage

```
make_planosol_canonical()
```

Value

A `PedonRecord`.

make_planossolo_canonical
Perfil canonico de Planossolo (SiBCS 5a ed., Cap 15)

Description

Solo com horizonte E sobrejacente a B planico (mudanca textural abrupta + cores neutras + cromas baixos).

Usage

```
make_planossolo_canonical()
```

make_plinthosol_canonical
Build the canonical Plinthosol fixture

Description

Synthetic seasonally-saturated tropical Plinthosol: A horizon with typical Cerrado SOC; Btv with diagnostic plinthite (25% by volume over 60 cm); persistent plinthite at depth. By construction:

- `plinthic`: PASSES on Btv and Cv.
- `argic`, `ferralic`, `mollic`, `spodic`, `calcic`, `gypsic`, `salic`: FAIL.

Usage

```
make_plinthosol_canonical()
```

Value

A `PedonRecord`.

make_plintossolo_canonical
Perfil canonico de Plintossolo (SiBCS 5a ed., Cap 16)

Description

Reusa fixture WRB Plinthosol – horizonte plintico iniciando dentro de 40 cm.

Usage

```
make_plintossolo_canonical()
```

make_podzol_canonical *Build the canonical Podzol fixture*

Description

Synthetic boreal / temperate-coniferous Podzol: bleached E (low clay, low CEC), illuvial Bs with diagnostic Al/Fe oxalate accumulation, weathered C. By construction:

- `spodic`: PASSES on Bs (Al_ox + 0.5*Fe_ox = 0.6, pH 4.5, 40 cm thick).
- `argic`, `ferralic`, `mollic`, `cambic`, `plinthic`, `calcic`, `gypsic`, `salic`: FAIL.

Usage

```
make_podzol_canonical()
```

Details

E horizon Munsell is set to chroma 3 (rather than canonical 1-2 of a true albic) to keep `gleyic_properties` clearly negative under the conservative v0.2 criterion.

Value

A `PedonRecord`.

make_retisol_canonical *Build the canonical Retisol fixture*

Description

Synthetic temperate Retisol on loess over clay-rich substrate: bleached E with glossic tongues penetrating the underlying argic Bt. By construction `retic_properties` passes via the "glossic" designation pattern; `argic` also passes (this is correct – Retisols are argic + retic features, and the WRB key tests RT before AC/LX/AL/LV).

Usage

```
make_retisol_canonical()
```

Value

A `PedonRecord`.

make_solonchak_canonical

Build the canonical Solonchak fixture

Description

Synthetic Solonchak from a coastal-arid setting: surface salt accumulation gives the diagnostic salic horizon (EC 25 dS/m over 25 cm); EC declines but stays elevated in the Bz; non-saline C below. By construction:

- salic: PASSES on Az.
- gypsic, calcic: FAIL.
- argic, ferralic, mollic: FAIL.

Usage

```
make_solonchak_canonical()
```

Value

A PedonRecord.

make_solonetz_canonical

Build the canonical Solonetz fixture

Description

Synthetic Solonetz on saline-sodic substrate: argic Btn with columnar structure and high exchangeable Na (ESP ~ 28%). By construction natric_horizon passes.

Usage

```
make_solonetz_canonical()
```

Value

A PedonRecord.

make_stagnosol_canonical

Build the canonical Stagnosol fixture

Description

Synthetic Stagnosol: redoximorphic features in a perched layer (Bg, 15-50 cm; redox 25%) but the deeper subsoil is well-drained (BC redox 2%, C redox 0). The decay-with-depth contrast is what distinguishes stagnic from gleyic. By construction `stagnic_properties` passes and `gleyic_properties` also passes (the surface redox qualifies for both); the WRB key tests Stagnosols (#16) and Gleysols (#9), so a real Stagnosol-typed fixture lands at Gleysols if both pass – the criteria differ in depth pattern, which is enough for the diagnostic functions but not for key precedence in v0.3. This is documented in the test as known overlap; v0.4 will add a stronger discriminator.

Usage

```
make_stagnosol_canonical()
```

Value

A `PedonRecord`.

make_synthetic_pedon_with_spectra

Build a synthetic PedonRecord with attached spectra (testing aid)

Description

Generates a small, deterministic `PedonRecord` with `n_horizons` horizons and a Vis-NIR spectral matrix (`350:2500` nm). Useful for exercising `fill_from_spectra` in tests and vignettes.

Usage

```
make_synthetic_pedon_with_spectra(
  n_horizons = 5L,
  wavelengths = 350:2500,
  seed = 1L
)
```

Arguments

`n_horizons`	Integer number of horizons (default 5).
`wavelengths`	Integer vector of wavelengths (default `350:2500`).

seed — Integer applied through with_seed so the synthetic spectra are reproducible *without* mutating the caller's global RNG state (the prior stream is restored on exit). Pass NULL to draw from the current RNG stream untouched. Default 1L keeps the bit-for-bit identical output that earlier soilKey releases produced, but does so via with_seed() (CRAN policy: never call set.seed() on the caller's RNG).

Value

A PedonRecord with a $spectra$vnir matrix attached.

---

make_technosol_canonical

Build the canonical Technosol fixture

Description

Synthetic urban / industrial Technosol: surface horizon with 30% anthropogenic artefacts (brick, glass, slag, plastic). By construction technic_features passes.

Usage

```
make_technosol_canonical()
```

Value

A PedonRecord.

---

make_umbrisol_canonical

Build the canonical Umbrisol fixture

Description

Synthetic humid-temperate Umbrisol on weathered acidic schist: deep organic-rich dark surface with low base saturation – the acid analogue of a Phaeozem. By construction umbric_horizon passes; mollic fails on BS < 50.

Usage

```
make_umbrisol_canonical()
```

Value

A PedonRecord.

`make_vertisol_canonical` *Build the canonical Vertisol fixture*

Description

Synthetic Vertisol from a smectite-rich plain: deep clay (50-55%) with strong slickensides in the Bss horizon. Surface chroma 4 (above the mollic cap) so that vertic_properties is the only v0.2 diagnostic that passes. By construction:

- `vertic_properties`: PASSES on Bss and BC.
- `argic`, `ferralic`, `mollic`, `cambic`, `plinthic`, `spodic`, `calcic`, `gypsic`, `salic`: FAIL.

Usage

```
make_vertisol_canonical()
```

Value

A `PedonRecord`.

`make_vertissolo_canonical` *Perfil canonico de Vertissolo (SiBCS 5a ed., Cap 17)*

Description

Solo argiloso (>= 30% argila desde superficie) com horizonte vertico (slickensides + fendas + clay alto) iniciando dentro de 100 cm. Reusa structure / fixture do WRB Vertisol.

Usage

```
make_vertissolo_canonical()
```

melanic_andisol_usda *Melanic Andisols: melanic_epipedon present.*

Description

Melanic Andisols: melanic_epipedon present.

Usage

```
melanic_andisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

melanic_epipedon_usda *Melanic epipedon (USDA Soil Taxonomy, 13th edition)*

Description

A thick, very dark, andic, organic-rich surface horizon associated with volcanic-ash-derived soils in cool, humid environments. Diagnostic for the Melanists / Melanudands great groups of Andisols.

Usage

```
melanic_epipedon_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

KST 13ed required characteristics (Ch. 3, pp 15-16):

- Upper boundary at or within 30 cm of the mineral soil surface (or organic layer with andic properties);
- Cumulative thickness >= 30 cm within 40 cm with all of:
  - Andic soil properties throughout;
  - Color value <= 2.5 moist AND chroma <= 2 throughout;
  - Melanic index <= 1.70 (deferred – specialized lab measurement);
  - OC >= 6 percent (weighted) AND >= 4 percent (each layer).

Implementation notes (v0.8.x):

- Andic soil properties are tested via `andic_properties_usda` (v0.9; for v0.8 we approximate with bulk_density <= 0.9 g/cm3 AND phosphate_retention >= 85%).
- Melanic index (= 100 / (OC * 100 + 1) per KST appendix) is deferred – requires UV-Vis spectroscopy.

Value

A DiagnosticResult.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, pp 15-16.

`mineral_material` *Mineral material (WRB 2022 Ch 3.3.11): < 20% SOC AND < 35% volume artefacts containing >= 20% organic carbon. The complement of organic_material / organotechnic_material.*

Description

Mineral material (WRB 2022 Ch 3.3.11): < 20% SOC AND < 35% volume artefacts containing >= 20% organic carbon. The complement of organic_material / organotechnic_material.

Usage

```
mineral_material(pedon, max_oc = 20, max_organotechnic = 35)
```

Arguments

`pedon`	A PedonRecord.
`max_oc`	Numeric threshold or option (see Details).
`max_organotechnic`	Numeric threshold or option (see Details).

`mollic` *Mollic horizon (WRB 2022)*

Description

Tests whether any near-surface horizon meets the mollic horizon criteria. The mollic horizon is the diagnostic surface horizon of Chernozems, Phaeozems, Kastanozems, and several other RSGs; it indicates a thick, dark, base-rich, organic-matter-enriched topsoil formed under steppe or comparable vegetation.

Usage

```
mollic(
  pedon,
  min_thickness = 20,
  min_oc = 0.6,
  min_bs = 50,
  surface_top_cm = 5
)
```

Arguments

pedon	A PedonRecord.
min_thickness	Minimum thickness in cm (default 20).
min_oc	Minimum SOC % (default 0.6).
min_bs	Minimum base saturation % (default 50).
surface_top_cm	Maximum top depth (cm) for a horizon to be considered "surface-related" (default 5). v0.1 uses this as a proxy for the WRB rule that mollic must form continuously from the soil surface (after mixing of upper 20 cm if required).

Details

Sub-tests called:

- `test_mollic_color` – moist value <= 3, moist chroma <= 3, dry value <= 5.
- `test_mollic_organic_carbon` – SOC >= 0.6%.
- `test_mollic_base_saturation` – BS (NH4OAc, pH 7) >= 50%.
- `test_mollic_thickness` – horizon thickness >= 20 cm.
- `test_mollic_structure` – not simultaneously massive AND very hard when dry.

v0.1 limitations: cumulative thickness across contiguous mollic- qualifying horizons is not yet supported – this matters for profiles where mollic criteria are met by an A1+A2 sequence but no single horizon is >= 20 cm thick. Mixing of upper 20 cm before the test (per WRB) is also deferred to v0.2.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022). *World Reference Base for Soil Resources*, 4th edition. International Union of Soil Sciences, Vienna. Chapter 3 – Mollic horizon.

`mollic_epipedon_usda` *Mollic epipedon (USDA Soil Taxonomy, 13th edition)*

Description

A thick, dark-colored, base-rich mineral surface horizon. The principal diagnostic horizon of the Mollisols order; also qualifies many subgroups of other orders as "Mollic" or "Pachic".

Usage

```
mollic_epipedon_usda(pedon, min_bs = 50, min_oc_pct = 0.6)
```

Arguments

`pedon`	A `PedonRecord`.
`min_bs`	Default 50 percent.
`min_oc_pct`	Default 0.6 percent.

Details

KST 13ed required characteristics (Ch. 3, pp 15-17):

- Color: dominant color value <= 3 (moist) AND <= 5 (dry) AND chroma <= 3 (moist), with adjustments for CaCO3 content (deferred to v0.9);
- Base saturation (NH4OAc, pH 7) >= 50 percent throughout;
- Organic carbon >= 0.6 percent (or 2.5 percent if value is 4-5 moist; or 0.6 absolute > C horizon);
- Thickness: 18 cm general, 25 cm if texture is loamy fine sand or coarser, 10 cm if directly above lithic/densic/ paralithic contact (`thin_lithic_overlay` branch);
- Structure: peds <= 30 cm OR rupture-resistance <= moderately hard;
- Some part moist 90+ days when soil temp at 50 cm is >= 5 C (deferred – requires climatic data).

Implementation notes (v0.8.x):

- Thickness rule is computed dynamically based on texture and presence of underlying lithic/paralithic contact.
- N value < 0.7 / fluidity nonfluid is assumed (laboratory tests rarely available);
- 90-day moisture condition is deferred to v0.9.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, pp 15-17.

`mollisol_qualifying_usda` *Mollisol Order qualifier (USDA, KST 13ed, Ch 12) Pass when mollic_epipedon AND BS (NH4OAc) >= 50% in upper 100 cm.*

Description

Mollisol Order qualifier (USDA, KST 13ed, Ch 12) Pass when mollic_epipedon AND BS (NH4OAc) >= 50% in upper 100 cm.

Usage

```
mollisol_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

mollisol_usda — *Mollisols (USDA Cap 12): mollic epipedon + base saturation >= 50%.*

Description

Mollisols (USDA Cap 12): mollic epipedon + base saturation >= 50%.

Usage

```
mollisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

mudanca_textural_abrupta — *Mudanca textural abrupta (SiBCS Cap 1, p 30-31)*

Description

Aumento consideravel de argila em pequena distancia vertical (\<= 7.5 cm) na transicao A/E -> B:

- argila A < 200 g/kg: argila B \>= 2x A; OR
- argila A 200-400 g/kg: incremento absoluto \>= 200 g/kg (i.e. de 300 -> 500); OR
- argila A \>= 400 g/kg: incremento absoluto \>= 220 g/kg (i.e. de 420 -> 640).

Reuso de abrupt_textural_difference (WRB Ch 3.2.1) que ja codifica criterios essencialmente equivalentes.

Usage

```
mudanca_textural_abrupta(pedon)
```

Arguments

pedon	A PedonRecord.

`mulmic_material` *Mulmic material (WRB 2022 Ch 3.3.12): mineral material developed from organic material; \>= 8% SOC, with low BD, structural / chroma criteria.*

Description

Mulmic material (WRB 2022 Ch 3.3.12): mineral material developed from organic material; \>= 8% SOC, with low BD, structural / chroma criteria.

Usage

```
mulmic_material(pedon, min_oc = 8, max_chroma = 2)
```

Arguments

`pedon`	A `PedonRecord`.
`min_oc`	Numeric threshold or option (see Details).
`max_chroma`	Numeric threshold or option (see Details).

`natric_horizon` *Natric horizon (WRB 2022)*

Description

Tests for the natric horizon: an argic horizon with diagnostic sodium accumulation (ESP >= 15%) within at least one argic layer. Diagnostic of Solonetz.

Usage

```
natric_horizon(pedon, min_esp = 15, min_pH_h2o = 7)
```

Arguments

`pedon`	A `PedonRecord`.
`min_esp`	Minimum ESP % (default 15).
`min_pH_h2o`	Minimum pH(H2O) for the ESP-only path (default 7.0; alkaline gate to exclude false-positive acidic Bt horizons).

Value

A `DiagnosticResult`.

v0.9.76 designation + ESP-only inference (opt-in)

Field-described Solonetz profiles in NCSS / KSSL data routinely reach the natric ESP threshold (computed from `na_cmol / cec_cmol`) without satisfying the strict `argic()` clay-increase test, because surveyors record `Btk`-suffix designations (carbonates dominate the horizon designation choice) rather than `Btn`/`Bn` or `clay_pct` is missing.

With `options(soilKey.natric_designation_inference = TRUE)` the function accepts a layer as natric when the canonical argic test returns NA or FALSE AND *either*:

1. the designation matches `[A-Z][a-z0-9]*n` (an `n` master-letter modifier in the horizon name – e.g.\ `Btn`, `Btnz`, `Bn`, the curator's direct assertion that natric features are present), OR
2. ESP >= `min_esp` on a B-prefixed subsoil layer (`top_cm > 20`) AND the layer's pH(H2O) >= 7 (alkaline – typical of true natric, excludes acidic Bt horizons that happen to read high Na from sea-spray).

Default is `FALSE` (canonical behaviour preserved).

References

IUSS Working Group WRB (2022), Chapter 3, Natric horizon.

`natric_horizon_usda` *Natric horizon helper (USDA, KST 13ed Ch 3)*

Description

Pass when natric_horizon (WRB natric: argillic + ESP > 15) is present.

Usage

```
natric_horizon_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

natric_subgroup_usda *Natric Subgroup helper for Natraquerts.*

Description

Natric Subgroup helper for Natraquerts.

Usage

```
natric_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

neossolo *Neossolos (SiBCS Cap 4, p 111-112; conceito Cap 3, p 96-97)*

Description

Solos pouco evoluidos: SEM horizonte B diagnostico + ausencia de: (a) glei dentro 150 cm, (b) plintico dentro 40 cm, (c) vertico imediatamente abaixo de A, (d) A chernozemico conjugado com carbonatico ou cálcico.

Usage

```
neossolo(pedon)
```

Arguments

pedon	A PedonRecord.

neossolo_fluvico *Neossolos Fluvicos (Cap 12): caracter fluvico em < 150 cm.*

Description

Neossolos Fluvicos (Cap 12): caracter fluvico em < 150 cm.

Usage

```
neossolo_fluvico(pedon)
```

Arguments

pedon	A PedonRecord.

neossolo_litolico *Neossolos Litolicos (Cap 12): contato litico ou litico fragmentario \<= 50 cm.*

Description

v0.9.29 adds an "implicit lithic contact" heuristic for the FEBR / BDsolos snapshot, where the surveyor often documents Neossolos Litolicos by simply stopping the profile description at the rock boundary (max profile depth \<= 50 cm with no horizon explicitly marked R / Cr / Rk and no B horizon described). Per SiBCS Cap 12 (p 219), Neossolos Litolicos are defined by lithic contact within 50 cm of the surface; in FEBR, this is signalled by the depth of the deepest described horizon rather than by an explicit pseudo-R record.

Usage

```
neossolo_litolico(pedon)
```

Arguments

pedon A PedonRecord.

Details

The heuristic fires only when:

1. the deepest `bottom_cm` value is \<= 50 cm,
2. no horizon designation begins with `B` (so we don't accidentally flag shallow Argissolos / Latossolos / etc. that have a Bt or Bw within 50 cm), AND
3. the canonical `contato_litico` / `contato_litico_ fragmentario` tests have NOT explicitly returned FALSE (i.e. the surveyor did not describe a non-rock material deeper than 50 cm).

Empirically, the heuristic flips ~190 of the 191 FEBR Litolicos from "neossolos regoliticos" (catch-all) to "neossolos litolicos" (correct), at the cost of a few false-positive Regoliticos that happen to be shallow (the FEBR confusion analysis showed only ~30 shallow Regoliticos).

neossolo_quartzarenico *Neossolos Quartzarenicos (Cap 12): textura areia/areia franca em todos os horizontes ate 150 cm + 95% quartzo.*

Description

Neossolos Quartzarenicos (Cap 12): textura areia/areia franca em todos os horizontes ate 150 cm + 95% quartzo.

Usage

```
neossolo_quartzarenico(pedon)
```

Arguments

pedon	A PedonRecord.

---

neossolo_regolitico *Neossolos Regoliticos (catch-all dos Neossolos).*

Description

Neossolos Regoliticos (catch-all dos Neossolos).

Usage

```
neossolo_regolitico(pedon)
```

Arguments

pedon	A PedonRecord.

---

nitic_horizon *Nitic horizon (WRB 2022)*

Description

Tests for the nitic horizon: a clay-rich (>= 30%), Fe-rich (DCB Fe >= 4%) subsurface horizon at least 30 cm thick. Diagnostic of Nitisols. WRB 2022 additionally requires polyhedral / nutty structure with shiny ped surfaces and a gradual (non-abrupt) clay decrease with depth.

Usage

```
nitic_horizon(
  pedon,
  min_clay = 30,
  min_fe_dcb = 4,
  min_thickness = 30,
  max_clay_drop_pct = 8,
  max_decrease_depth = 50
)
```

Arguments

pedon	A PedonRecord.
min_clay	Minimum clay % (default 30).
min_fe_dcb	Minimum DCB-extractable Fe % (default 4).
min_thickness	Minimum thickness in cm (default 30).
max_clay_drop_pct	Maximum clay drop (percentage points) between adjacent layers within max_decrease_depth before failing the gradual-decrease test (default 8).
max_decrease_depth	Depth window (cm) for the gradual-decrease check (default 50).

Details

Required (AND-combined) sub-tests:

- Profile does not have a ferralic horizon (Ferralsol path is canonical for the clay-rich + low-CEC corner).
- clay % >= min_clay.
- fe_dcb_pct >= min_fe_dcb.
- thickness >= min_thickness.

Supplementary (soft-AND) sub-tests – evaluated when evidence is present in the pedon, evaluate to NA (not a fail) when missing:

- structure_type matches polyhedral / nutty / (sub)angular blocky.
- slickensides / shiny ped surfaces present (proxy for WRB's "shiny ped surfaces").
- clay does not decrease abruptly between adjacent layers within 50 cm of the surface (gradual-decrease pattern; drop > 8 percentage points fails).

Supplementary tests fail (return passed = FALSE) only when evidence actively contradicts the criterion; missing evidence is permissive.

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 3, Nitic horizon.

nitossolo — *Nitossolos (SiBCS Cap 4, p 114; conceito Cap 3, p 97-98)*

Description

\>= 350 g/kg argila incluindo no horizonte A, com B nitico abaixo do A, com argila ativ baixa OR ativ alta + carater alumínico, na maior parte dos primeiros 100 cm do B (incl. BA).

Usage

```
nitossolo(pedon)
```

Arguments

pedon	A PedonRecord.

nitossolo_bruno — *Nitossolos Brunos (Cap 13): matiz \>= 7.5YR + valor <= 4 + croma <= 5.*

Description

Nitossolos Brunos (Cap 13): matiz \>= 7.5YR + valor <= 4 + croma <= 5.

Usage

```
nitossolo_bruno(pedon)
```

Arguments

pedon	A PedonRecord.

nitossolo_haplico — *Nitossolos Haplicos (catch-all).*

Description

Nitossolos Haplicos (catch-all).

Usage

```
nitossolo_haplico(pedon)
```

Arguments

pedon	A PedonRecord.

nitossolo_vermelho — *Nitossolos Vermelhos (Cap 13): matiz \<= 2.5YR.*

Description

Nitossolos Vermelhos (Cap 13): matiz \<= 2.5YR.

Usage

```
nitossolo_vermelho(pedon)
```

Arguments

pedon	A PedonRecord.

nitric_subgroup_usda — *Nitric Subgroup helper (Anhyturbels / Anhyorthels)*

Description

Pass when a horizon >= 15 cm thick has nitrate concentration >= 118 mmol(-)/L AND (thickness * concentration) >= 3500. (Nitrate is not in the schema; v0.8 returns NA with missing flag.)

Usage

```
nitric_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

normalise_febr_sibcs *Canonicalise FEBR SiBCS names to match soilKey rule outputs.*

Description

FEBR ships SiBCS labels in mixed legacy/modern form ("Podzolicos" for old name of Argissolos, singular vs plural, Portuguese accents). This helper folds them to the form produced by `run_sibcs_key()` so that benchmark accuracies can be computed without false negatives.

Usage

```
normalise_febr_sibcs(x, level = c("order", "subordem"))
```

Arguments

`x`	Character vector of FEBR SiBCS names.
`level`	One of `"order"` (default) or `"subordem"`.

Value

Character vector of normalised SiBCS names; `NA` for labels that are out-of-scope for the comparison (e.g.\ legacy `"Solos"` category).

See Also

`normalise_febr_wrb`, `normalise_febr_usda`

normalise_febr_usda *Normalise FEBR USDA taxon strings to USDA Soil Taxonomy Order*

Description

FEBR ships USDA Soil Taxonomy labels at the subgroup or great-group granularity (e.g. "TYPIC HAPLUDULT", "ACRUSTOX"). The suffix of the final word encodes the Order: `...OX` -> Oxisols, `...ULT` -> Ultisols, `...EPT` -> Inceptisols, etc. This helper extracts the Order from the suffix so the benchmark can compare against `classify_usda()$rsg_or_order` at `level = "order"`.

Usage

```
normalise_febr_usda(x)
```

Arguments

`x`	Character vector of FEBR USDA names.

Value

Character vector of normalised Order names ("Oxisols", "Ultisols", "Inceptisols", ...).

normalise_febr_wrb *Normalise FEBR WRB taxon strings to RSG-only*

Description

FEBR ships WRB names with full qualifier strings, e.g. "HUMIC FERRALSOL", "HAPLIC ACRISOL (ALUMIC, HYPERDYSTRIC, ...)". The trailing word (before any qualifier parens) is the RSG. This helper extracts and normalises it to soilKey's plural Title Case form ("Ferralsols", "Acrisols"), matching `ClassificationResult$rsg_or_order`.

Usage

```
normalise_febr_wrb(x)
```

Arguments

x	Character vector of FEBR WRB names.

Value

Character vector of normalised RSG names.

normalise_kssl_subgroup *Normalise KSSL USDA subgroup labels for benchmark comparison*

Description

KSSL stores 'samp_taxsubgrp' in lower-case, space-separated form ("typic hapludalfs", "aquic argiudolls"). soilKey's 'classify_usda()' returns Title Case names ("Typic Hapludalfs"). The benchmark runner at 'level = "subgroup"' lowercases both sides and trims whitespace, but this helper makes the normalisation explicit when users want to compare KSSL labels against arbitrary classifier output. Idempotent.

Usage

```
normalise_kssl_subgroup(x)
```

Arguments

x	Character vector of KSSL subgroup names.

Value

Lowercase, single-space-separated vector.

ochric_epipedon_usda *Ochric epipedon (USDA Soil Taxonomy, 13th edition)*

Description

The catch-all surface epipedon: any A horizon (or surface horizon with pedogenic alteration) that does NOT meet the specific requirements of histic, folistic, melanic, mollic, umbric, anthropic or plaggen.

Usage

```
ochric_epipedon_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

KST 13ed (Ch 3, p 17): "The ochric epipedon fails to meet the definitions for any of the other seven epipedons because it is too thin or too dry, has too high a color value or chroma, contains too little organic carbon, has too high an n value, has too high a fluidity class or melanic index, or is both massive and hard or harder when dry."

Implementation: pass when none of the 6 implemented epipedons (histic, folistic, melanic, mollic, umbric – v0.8 implements 5; anthropic / plaggen are deferred to v0.9 but rare) pass AND the profile has at least one surface A horizon.

Value

A DiagnosticResult.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, p 17.

ollama_is_running *Is the local Ollama HTTP API reachable?*

Description

Probes `http://127.0.0.1:11434/api/tags` (the standard Ollama endpoint) with a short HTTP HEAD-style GET. Returns `TRUE` only if the request returns HTTP 200 in under `timeout_s` seconds. Used by vlm_pick_provider for the `provider = "auto"` fallback chain. Override the URL via `options(soilKey.ollama_url = "http://host:port")`.

Usage

```
ollama_is_running(url = NULL, timeout_s = 1.5)
```

Arguments

url	Override URL to probe (default reads `getOption("soilKey.ollama_url",default = "http://127.0.0.1:11434/api/tags")`).
timeout_s	Request timeout in seconds (default 1.5).

Value

Logical scalar.

---

organic_material *Organic material (WRB 2022 Ch 3.3.13): \>= 20% SOC + recognisability criteria. v0.3.3: SOC threshold only.*

Description

Organic material (WRB 2022 Ch 3.3.13): \>= 20% SOC + recognisability criteria. v0.3.3: SOC threshold only.

Usage

```
organic_material(pedon, min_oc = 20)
```

Arguments

pedon	A PedonRecord.
min_oc	Numeric threshold or option (see Details).

---

organossolo *Organossolos (SiBCS Cap 4, chave do 1o nivel; conceito Cap 3, p 99-101)*

Description

Solos com horizonte hístico atendendo a um dos criterios de espessura: \>= 20 cm sobre rocha, \>= 40 cm continuo OR cumulativo nos 80 cm superficiais, OR \>= 60 cm se \>= 75% volume tecido vegetal.

Usage

```
organossolo(pedon)
```

Arguments

pedon	A PedonRecord.

`organossolo_folico` *Organossolos Folicos (Cap 14): horizonte O histico (drenado). Detectado via designation pattern \"^O\".*

Description

Organossolos Folicos (Cap 14): horizonte O histico (drenado). Detectado via designation pattern \"^O\".

Usage

```
organossolo_folico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`organossolo_haplico` *Organossolos Haplicos (catch-all).*

Description

Organossolos Haplicos (catch-all).

Usage

```
organossolo_haplico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`organossolo_tiomorfico` *Organossolos Tiomorficos (Cap 14): materiais sulfidricos OR horizonte sulfurico em < 100 cm.*

Description

Organossolos Tiomorficos (Cap 14): materiais sulfidricos OR horizonte sulfurico em < 100 cm.

Usage

```
organossolo_tiomorfico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`organotechnic_material` *Organotechnic material (WRB 2022 Ch 3.3.14): \>= 35% volume of artefacts that themselves contain \>= 20% organic C. Soil itself has < 20% SOC.*

Description

Organotechnic material (WRB 2022 Ch 3.3.14): \>= 35% volume of artefacts that themselves contain \>= 20% organic C. Soil itself has < 20% SOC.

Usage

```
organotechnic_material(pedon, min_artefacts = 35, max_oc = 20)
```

Arguments

`pedon`	A `PedonRecord`.
`min_artefacts`	Numeric threshold or option (see Details).
`max_oc`	Numeric threshold or option (see Details).

`ornithogenic_material` *Ornithogenic material (WRB 2022 Ch 3.3.15): bird-influenced topsoil. Mehlich-3 P >= 750 mg/kg + designation pattern* `Aornit|Bornit`*.*

Description

Ornithogenic material (WRB 2022 Ch 3.3.15): bird-influenced topsoil. Mehlich-3 P >= 750 mg/kg + designation pattern `Aornit|Bornit`.

Usage

```
ornithogenic_material(pedon, min_p_mehlich3 = 750)
```

Arguments

`pedon`	A `PedonRecord`.
`min_p_mehlich3`	Numeric threshold or option (see Details).

`ossl_demo_sa` *Synthetic OSSL South America demo subset*

Description

A small, deterministic, OSSL-shaped artefact for use in vignettes, examples and tests when the real Open Soil Spectral Library data is not available (no network, sensitive deployment, CI). The object has the canonical `list(Xr, Yr, metadata)` shape consumed by `predict_ossl_mbl` / `fill_from_spectra`, so the in-package demo path is identical to the real-data path.

Usage

```
ossl_demo_sa
```

Format

A list with three elements:

`Xr` Numeric matrix, 80 rows (synthetic profiles) x 2151 columns (wavelengths 350-2500 nm). Reflectance values in [0.05, 0.85].

`Yr` Data frame, 80 rows x 9 columns (`clay_pct`, `sand_pct`, `silt_pct`, `cec_cmol`, `bs_pct`, `ph_h2o`, `oc_pct`, `fe_dcb_pct`, `caco3_pct`). Property ranges follow the OSSL global summary statistics.

`metadata` Named list with provenance information (`region`, `n_profiles`, `snapshot`, `seed`, `note`, ...).

Details

This is a **synthetic** placeholder: the spectra are generated from a tropical-soil baseline plus property-correlated absorption bands (1400 nm OH-water, 1900 nm clay-OH, 2200 nm Al-OH, 900 nm Fe-oxide) with deterministic noise. It is *not* a substitute for real OSSL measurements. For paper-grade work, populate a real OSSL artefact via:

```
ossl_lib <- download_ossl_subset(region = "south_america")
```

Re-build the demo with `source("data-raw/build_ossl_demo.R")`.

Source

Synthetic; built by `data-raw/build_ossl_demo.R` with seed 20260430. The OSSL property ranges that drove the simulation come from Sanderman, J. *et al.* (2024), *Open Soil Spectral Library*, https://soilspectroscopy.org/.

Examples

```
data(ossl_demo_sa)
dim(ossl_demo_sa$Xr)
#> [1]   80 2151
head(ossl_demo_sa$Yr)


# Use it as the ossl_library argument to predict_ossl_mbl():
pedon <- make_synthetic_pedon_with_spectra()
fill_from_spectra(pedon,
                  library      = "ossl",
                  method       = "mbl",
                  ossl_library = ossl_demo_sa)
```

---

ossl_library_template *Canonical schema for an ‘ossl_library‘ object*

Description

predict_ossl_mbl and predict_ossl_plsr_local take an `ossl_library` argument that must be a list with two named elements:

Usage

```
ossl_library_template(
  wavelengths = 350:2500,
 properties = c("clay_pct", "sand_pct", "silt_pct", "cec_cmol", "bs_pct", "ph_h2o",
    "oc_pct", "fe_dcb_pct", "caco3_pct")
)
```

Arguments

wavelengths	Integer vector of wavelengths (default `350:2500` nm for Vis-NIR/SWIR).
properties	Character vector of property column names to seed the empty `Yr` data.frame with.

Details

- `Xr`: numeric matrix, rows = OSSL training spectra, columns = wavelengths. Must align (after preprocessing) with the column space used by the spectra you predict on.
- `Yr`: data.frame keyed by property name (e.g. `clay_pct`, `cec_cmol`), one row per training spectrum.

This function returns an empty template you can populate from a real OSSL extract (e.g. via the `ossl-import` Python package or the public S3 mirror at `https://storage.googleapis.com/soilspec4gg-public/`).

soilKey does **not** bundle OSSL data; until you populate this template with real values, all 'predict_ossl_*' calls fall back to the deterministic synthetic predictor (which prints a warning).

Value

A list with `Xr` (a 0-row matrix of the right column dimension) and `Yr` (an empty data.frame with the requested columns).

---

oxic_horizon_usda — *Oxic horizon (USDA, KST 13ed, Ch 3) Delegates to WRB* `ferralic`.

Description

Oxic horizon (USDA, KST 13ed, Ch 3) Delegates to WRB `ferralic`.

Usage

```
oxic_horizon_usda(pedon)
```

Arguments

pedon	A PedonRecord.

oxic_usda *Oxic horizon (USDA Soil Taxonomy)*

Description

The USDA oxic horizon is the diagnostic of Oxisols. Its central criteria match the WRB 2022 ferralic horizon closely enough that v0.2 simply delegates: every fixture that classifies as Oxisol via USDA also classifies as Ferralsol via WRB and vice-versa. The fine-grained differences (USDA's water-dispersible-clay test, the sand-fraction weatherable-mineral cut-offs) are tracked in the diagnostics.yaml for v0.8 refinement.

Usage

```
oxic_usda(pedon, ...)
```

Arguments

pedon	A PedonRecord.
...	Passed to ferralic.

Value

A DiagnosticResult (with name = "oxic_usda").

References

Soil Survey Staff (2014). *Keys to Soil Taxonomy*, 12th edition. USDA-NRCS, Washington DC. Chapter 3 – Diagnostic Horizons; oxic.

oxisol_usda *Oxisol (USDA Cap 13): oxic horizon, excluding profiles with an argillic horizon overlying the oxic.*

Description

v0.9.17 fix: KST 13ed Ch 13 (p 295) excludes from Oxisols any profile whose argillic horizon's upper boundary lies within 100 cm of the surface AND whose argillic base lies within 30 cm of the upper boundary of the oxic. Operationally we use the simpler and more defensible "argillic above oxic" check: if argillic exists and starts strictly shallower than the oxic, the profile is NOT an Oxisol (route to Ultisols / Alfisols instead). The previous v0.8 implementation lacked this exclusion and was responsible for misclassifying 144 Embrapa FEBR Ultisols as Oxisols in the v0.9.16 benchmark.

Usage

```
oxisol_usda(pedon)
```

Arguments

`pedon` A `PedonRecord`.

`oxyaquic_subgroup_usda` *Oxyaquic Subgroup helper (Spodosols, Mollisols, etc.)*

Description

Pass when the soil is saturated with water in one or more layers within 100 cm of the mineral soil surface for either or both:

- 20+ consecutive days; OR
- 30+ cumulative days.

Usage

```
oxyaquic_subgroup_usda(pedon)
```

Arguments

`pedon` A `PedonRecord`.

Details

v0.8 proxy: pass when redoximorphic features OR low chroma in any layer within 100 cm (subset of full aquic conditions).

Value

A `DiagnosticResult`.

`pachic_subgroup_usda` *Pachic Subgroup helper (Andisols, Mollisols) Pass when mollic OR umbric epipedon is >= 50 cm thick.*

Description

Pachic Subgroup helper (Andisols, Mollisols) Pass when mollic OR umbric epipedon is >= 50 cm thick.

Usage

```
pachic_subgroup_usda(pedon)
```

Arguments

`pedon` A `PedonRecord`.

`paleargid_qualifying_usda`
Paleargid qualifying helper Pass when argillic horizon has continuous clay films AND clay » 35% in upper 10 cm (proxy for old, well-developed argillic). v0.8 proxy: argillic + clay_pct >= 35 in upper 30 cm.

Description

Paleargid qualifying helper Pass when argillic horizon has continuous clay films AND clay » 35% in upper 10 cm (proxy for old, well-developed argillic). v0.8 proxy: argillic + clay_pct >= 35 in upper 30 cm.

Usage

```
paleargid_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`pale_qualifying_usda`
Pale qualifying helper (Paleudults / Paleustults / Palexerults / Palehumults / Paleaquults)

Description

Pass when an argillic horizon has either:

- clay >= 35% in upper 30 cm of argillic; OR
- lithologic discontinuity NOT followed by argic; OR
- argillic that does NOT decrease in clay >= 20% relative from its maximum.

v0.8 proxy: clay_pct >= 35% in upper argillic.

Usage

```
pale_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`panpaic` *Panpaic horizon (WRB 2022 Ch 3.1)*

Description

From Quechua *p'anpay* = "to bury". A buried diagnostic horizon (any horizon whose original surface was subsequently overlain by younger material). Used by the Panpaic qualifier and by the Cambisols / Anthrosols branches.

Usage

```
panpaic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Details

v0.3.5 detection: designation pattern starting with a digit other than 1 (e.g. `2A`, `2Bw`, `3C`) – the WRB / FAO convention for buried horizons – OR a `b` suffix in the designation (e.g. `Ahb`, `Bwb`).

`PedonRecord` *PedonRecord: structured representation of a single pedon*

Description

PedonRecord: structured representation of a single pedon

PedonRecord: structured representation of a single pedon

Details

The central data carrier in soilKey. A PedonRecord bundles everything we know about one soil profile: site metadata, the horizons table (with a fixed canonical schema — see `horizon_column_spec`), optional Vis-NIR/MIR spectra, profile photographs, source documents, and a provenance log that records, per (horizon, attribute) pair, where each value came from (`measured`, `extracted_vlm`, `predicted_spectra`, `inferred_prior`, `user_assumed`).

All diagnostic functions (`argic`, `ferralic`, `mollic`, ...) consume a PedonRecord directly. The provenance log is what allows the final `ClassificationResult` to assign a meaningful evidence grade.

Public fields

`site` List. Site-level metadata: `lat`, `lon`, `crs` (default 4326), `date`, `country`, `elevation_m`, `slope_pct`, `aspect_deg`, `landform`, `parent_material`, `land_use`, `vegetation`, `drainage_class`, plus an arbitrary `id`.

`horizons` data.table with the canonical horizon schema.

`spectra` List with optional `vnir` matrix (rows = horizons, cols = wavelengths in nm), `mir` matrix, and `metadata` list.

`images` List of named lists describing profile photographs.

`documents` List of named lists describing source documents.

`provenance` data.table with columns `horizon_idx`, `attribute`, `source`, `confidence`, `notes`.

Methods

Public methods:

- PedonRecord$new()
- PedonRecord$validate()
- PedonRecord$to_aqp()
- PedonRecord$from_aqp()
- PedonRecord$add_measurement()
- PedonRecord$summary()
- PedonRecord$print()
- PedonRecord$clone()

Method `new()`**:** Construct a PedonRecord.

Usage:

```
PedonRecord$new(
  site = NULL,
  horizons = NULL,
  spectra = NULL,
  images = NULL,
  documents = NULL,
  provenance = NULL
)
```

Arguments:

`site` List of site-level metadata.

`horizons` data.frame/data.table of horizons.

`spectra` Optional list with `vnir`, `mir`, `metadata`.

`images` Optional list of image descriptors.

`documents` Optional list of document descriptors.

`provenance` Optional provenance data.table; if NULL, an empty one is created.

Method `validate()`**:** Validate the record against soil-physical sanity rules.

Checks: top < bottom for every horizon; no overlapping depths; clay+silt+sand sum to 100 ± 2 where all three are reported; pH values plausible (1..12); CEC >= sum of exchangeable bases (Ca, Mg, K, Na); Munsell value/chroma in plausible ranges; coarse fragments percent in [0, 100]; OC geographic ranges. Returns a list with `valid`, `errors`, `warnings`, `n_horizons`.

Usage:

```
PedonRecord$validate(strict = FALSE, verbose = TRUE)
```

Arguments:

`strict` If `TRUE`, throws on errors instead of returning.

`verbose` If `TRUE`, prints messages via cli.

Returns: Invisibly, a list summarising the validation outcome.

Method `to_aqp()`**:** Coerce to an aqp `SoilProfileCollection`.

Usage:

```
PedonRecord$to_aqp()
```

Returns: A `SoilProfileCollection`. Requires the aqp package.

Method `from_aqp()`**:** Populate this record from an aqp `SoilProfileCollection`.

Usage:

```
PedonRecord$from_aqp(spc, top_col = "top_cm", bottom_col = "bottom_cm")
```

Arguments:

`spc` A `SoilProfileCollection`.

`top_col` Name of the top-depth column in `spc` (mapped to `top_cm`).

`bottom_col` Name of the bottom-depth column (mapped to `bottom_cm`).

Returns: Invisibly self (mutated in place).

Method `add_measurement()`**:** Add a measurement (or extracted/predicted value) and record its provenance.

Usage:

```
PedonRecord$add_measurement(
  horizon_idx,
  attribute,
  value,
  source = "measured",
  confidence = 1,
  notes = NA_character_,
  overwrite = FALSE
)
```

Arguments:

`horizon_idx` Integer horizon index (1-based).

`attribute` Name of the horizon column to set.

`value` New value for that cell.

`source` One of "measured", "extracted_vlm", "predicted_spectra", "inferred_prior", "user_assumed".

`confidence` Numeric in [0, 1].

`notes` Optional free-text note.

`overwrite` If `FALSE` (default) and the cell already has a value from a more authoritative source, leave it alone. If `TRUE`, overwrite.

Returns: Invisibly self.

Method `summary()`**:** Compact summary list (for serialization or testing).

Usage:

`PedonRecord$summary(...)`

Arguments:

`...` Ignored (S3 summary signature compatibility).

Method `print()`**:** Pretty-print the record.

Usage:

`PedonRecord$print(...)`

Arguments:

`...` Ignored (S3 print signature compatibility).

Method `clone()`**:** The objects of this class are cloneable with this method.

Usage:

`PedonRecord$clone(deep = FALSE)`

Arguments:

`deep` Whether to make a deep clone.

`pedon_json_schema` *JSON Schema for a soilKey PedonRecord*

Description

Returns a Draft-2020-12 JSON Schema describing the canonical `PedonRecord` structure: a `site` object with site-level metadata plus a `horizons` array where each element matches the canonical horizon schema documented by `horizon_column_spec`.

Usage

```
pedon_json_schema(as = c("list", "json"), pretty = TRUE)
```

Arguments

`as`	One of `"list"` (default; returns a structured R list ready to serialise) or `"json"` (returns a JSON string; requires the `jsonlite` package).
`pretty`	Logical, only used for `as = "json"`.

Value

A list (default) or a JSON string.

Examples

```
schema <- pedon_json_schema()
names(schema)


# Validate a JSON profile against the schema:
if (requireNamespace("jsonvalidate", quietly = TRUE) &&
      requireNamespace("jsonlite", quietly = TRUE)) {
  schema_json <- pedon_json_schema(as = "json")
  p <- make_ferralsol_canonical()
  p_json <- jsonlite::toJSON(list(site = p$site,
                                  horizons = list()),
                             auto_unbox = TRUE, null = "null")
  jsonvalidate::json_validate(p_json, schema_json, engine = "ajv")
}
```

---

pedon_to_spc   *Convert a soilKey PedonRecord to an aqp SoilProfileCollection*

Description

The mapping respects aqp's expected column conventions and sets the metadata required by `getArgillicBounds()`, `getCambicBounds()`, and `mollicEpipedon()`:

Usage

```
pedon_to_spc(pedon)
```

Arguments

pedon	A PedonRecord.

Details

- `id` from `pedon$site$id`
- `top` / `bottom` from `top_cm` / `bottom_cm`
- `name` (designation) from `designation`
- `texcl` (texture class) derived via `texture_class_from_pct`
- `clay`, `silt`, `sand` from `clay_pct` / `silt_pct` / `sand_pct`
- `m_hue`, `m_value`, `m_chroma`, `d_value`, `d_chroma` from `munsell_*_moist` and `munsell_*_dry`

Internal use; the soilKey diagnostics call this on the fly when `engine = "aqp"`. Direct use is supported for users who want to plug additional aqp algorithms (`slab`, `slice`, `glom`) into a soilKey workflow.

Value

A `aqp::SoilProfileCollection` with one site (the pedon) and one row per horizon.

permafrost_within_usda *Permafrost (USDA Soil Taxonomy, 13th edition)*

Description

"Permafrost is defined as a thermal condition in which a material (including soil material) remains below 0 C for 2 or more years in succession." – KST 13ed, Ch 3, p 47.

Usage

```
permafrost_within_usda(pedon, max_top_cm = 100)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Maximum depth where permafrost must occur (default 100 cm – Gelisols criterion at Order level).

Details

Permafrost is the defining characteristic of the Gelisols order (within 100 cm of the soil surface) and qualifies many subgroups across Histosols (Histels), Inceptisols, and others.

Implementation: Uses `permafrost_temp_C` from schema. A layer qualifies as permafrost when its `permafrost_temp_C` is <= 0 C. The function checks whether any qualifying layer occurs within `max_top_cm` of the surface.

Value

A DiagnosticResult.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, p 47.

petrocalcic *Petrocalcic horizon (WRB 2022)*

Description

A continuously cemented variant of the calcic horizon. Same chemistry (CaCO3 \>= 15%) plus moderate-or-greater cementation in at least 50% of the layer.

Usage

```
petrocalcic(pedon, min_thickness = 10, min_caco3_pct = 15)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
min_caco3_pct	Numeric threshold or option (see Details).

---

petrocalcic_subgroup_usda   *Petrocalcic Subgroup helper (Aridisols Petrocalcids) Cemented calcic horizon with cementation_class >= "strongly".*

Description

Petrocalcic Subgroup helper (Aridisols Petrocalcids) Cemented calcic horizon with cementation_class >= "strongly".

Usage

```
petrocalcic_subgroup_usda(pedon, max_top_cm = 100)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Numeric threshold or option (see Details).

---

petroduric   *Petroduric horizon (WRB 2022): cemented duric.*

Description

Petroduric horizon (WRB 2022): cemented duric.

Usage

```
petroduric(pedon, min_thickness = 10, min_duripan_pct = 10)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
min_duripan_pct	Numeric threshold or option (see Details).

petroferric_contact_usda

Petroferric contact helper (USDA, KST 13ed Ch 3, p 48)

Description

Ironstone-like layer with >50% Fe oxides, indurated. v0.8 proxy: `cementation_class` in {strongly, indurated} AND `plinthite_pct >= 50` (Fe-rich) AND `coarse_fragments_pct >= 50`.

Usage

```
petroferric_contact_usda(pedon, max_top_cm = 125)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Default 125.

Value

A `DiagnosticResult`.

petrogypsic

Petrogypsic horizon (WRB 2022): cemented gypsic.

Description

Petrogypsic horizon (WRB 2022): cemented gypsic.

Usage

```
petrogypsic(pedon, min_thickness = 10, min_gypsum_pct = 5)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).
`min_gypsum_pct`	Numeric threshold or option (see Details).

---

petrogypsic_horizon_usda

Petrogypsic horizon helper (USDA)

Description

Pass when a horizon has `cementation_class` in {strongly, indurated} AND `caso4_pct` >= 5 within `max_top_cm`.

Usage

```
petrogypsic_horizon_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Default 100.

Value

A `DiagnosticResult`.

---

petrogypsic_subgroup_usda

Petrogypsic Subgroup helper – delegate to petrogypsic_horizon_usda

---

Description

Petrogypsic Subgroup helper – delegate to petrogypsic_horizon_usda

Usage

```
petrogypsic_subgroup_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`petronodic_subgroup_usda` *Petronodic Subgroup helper (Aridisols) Pass when 5%+ rock fragments cemented by carbonates within 100 cm. v0.8 proxy: caco3_pct >= 15 AND coarse_fragments_pct >= 5.*

Description

Petronodic Subgroup helper (Aridisols) Pass when 5%+ rock fragments cemented by carbonates within 100 cm. v0.8 proxy: caco3_pct >= 15 AND coarse_fragments_pct >= 5.

Usage

```
petronodic_subgroup_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`petroplinthic` *Petroplinthic horizon (WRB 2022): cemented plinthic.*

Description

Petroplinthic horizon (WRB 2022): cemented plinthic.

Usage

```
petroplinthic(pedon, min_thickness = 10, min_plinthite_pct = 15)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).
`min_plinthite_pct`	Numeric threshold or option (see Details).

`phaeozem` *Phaeozem RSG diagnostic (WRB 2022)*

Description

Tests whether a profile satisfies the Phaeozem RSG criteria: a mollic horizon AND no secondary carbonate accumulation anywhere in the profile.

Usage

```
phaeozem(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Phaeozems.

`pick_engine` *Choose the best diagnostic engine for a single pedon*

Description

Per-pedon heuristic: returns `"aqp"` if the pedon's horizon table has the morphological richness that makes aqp's canonical NRCS dispatch reliable, otherwise returns `"soilkey"` (the more permissive hand-coded path).

Usage

```
pick_engine(pedon, min_score = 3L)
```

Arguments

`pedon`	A `PedonRecord`.
`min_score`	Integer (1-5). Minimum completeness score for `"aqp"` engine to fire (default 3).

Value

Character: `"aqp"` or `"soilkey"`.

Heuristic

We score each pedon on a 0-5 morphology-completeness scale; aqp fires when score \>= `min_score` (default 3). The five axes:

1. **Designation present** (any layer has a non-blank `designation`, e.g. "A1", "Bt2", "Bw").
2. **Texture quantitative** (any layer has both `clay_pct` and `sand_pct` populated).
3. **Munsell complete** (any layer has all three of `munsell_hue_moist`, `munsell_value_moist`, `munsell_chroma_moist` populated).
4. **Structure recorded** (any layer has a non-blank `structure_grade`).
5. **Clay films / argic evidence** (any layer has a non-blank `clay_films_amount` or designation pattern matching `Bt`).

Why this matters

On BDsolos RJ (data-rich), the heuristic recommends aqp for ~99 canonical thresholds). On LUCAS topsoil-only (data-sparse), it recommends aqp for ~0 clay-films / designation axes are unfilled. Calling `classify_*(pedon)` routed through the heuristic gives the correct engine per pedon, recovering both the BDsolos RJ lift AND the LUCAS robustness.

See Also

`argic`, `cambic`.

`pick_engine_batch` *Per-pedon batch engine recommendation*

Description

Vectorised version of `pick_engine` returning the recommended engine for each pedon in a list.

Usage

```
pick_engine_batch(pedons, min_score = 3L)
```

Arguments

`pedons`	A list of `PedonRecord` objects.
`min_score`	Integer; forwarded to `pick_engine`.

Value

Character vector of length(pedons) with values "aqp" or "soilkey".

`pisoplinthic` *Pisoplinthic horizon (WRB 2022): pisolitic plinthic. v0.3.3 detects via designation pattern* `Bspl` / `Bvpi` *or via plinthite* `\>=` *15% AND structure_type containing 'pisol'.*

Description

Pisoplinthic horizon (WRB 2022): pisolitic plinthic. v0.3.3 detects via designation pattern `Bspl` / `Bvpi` or via plinthite \>= 15% AND structure_type containing 'pisol'.

Usage

```
pisoplinthic(pedon, min_thickness = 15, min_plinthite_pct = 15)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).
`min_plinthite_pct`	Numeric threshold or option (see Details).

`pi_to_confidence` *Map a 95% prediction interval to a [0, 1] confidence score*

Description

Tightens confidence as the prediction interval narrows relative to the predicted value: `confidence = 1 - (PI95_width / |value|) / 4`, floored at 0 and capped at 1. When `value` is near zero we fall back to an absolute-width heuristic so we never blow up.

Usage

```
pi_to_confidence(pi95_low, pi95_high, value = NULL)
```

Arguments

`pi95_low`	Lower 2.5% quantile of the prediction.
`pi95_high`	Upper 97.5% quantile of the prediction.
`value`	Optional point prediction. When supplied, normalisation is by `|value|`; otherwise by `|midpoint|`.

Details

Properties of the mapping:

- Zero-width interval -> confidence = 1.
- Interval whose width equals `|value| * 4` -> confidence = 0.
- NA value or NA bounds -> confidence = 0.5 (neutral).

Value

Numeric in `[0, 1]`.

`placic_horizon_usda` *Placic horizon (USDA, KST 13ed Ch 3, pp 47-48)*

Description

Pass when a thin (1-25 mm) Fe/Mn-cemented horizon is present. Detected via designation containing 'm' (cemented) AND `cementation_class` in {strongly, indurated} AND thickness between 1 mm and 25 mm.

Usage

```
placic_horizon_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Default 100.

Value

A `DiagnosticResult`.

plaggic — *Plaggic horizon (WRB 2022): sod-derived topsoil >= 20 cm with low BD AND independent evidence of human input.*

Description

v0.9.2.C tightening: the v0.3.3 implementation accepted ANY thick, low-BD, OC-rich A horizon, which over-fired across natural mollic / umbric / chernic surfaces. The diagnostic now requires, in addition to the OC + BD + thickness baseline, at least one independent anthropogenic-input marker:

- `p_mehlich3_mg_kg >= 50` (sustained sod / manure additions concentrate Mehlich-3 P in the topsoil), OR
- `artefacts_pct > 0` (any human artefact volume fraction is sufficient as a presence signal), OR
- designation pattern `Apl` / `Aplg` / `Apk` / explicit "plagg".

Without one of those markers the diagnostic returns FALSE even when OC + BD + thickness pass. This mirrors the v0.9.1 `qual_plaggic` gate but enforces the rule at the diagnostic level so any caller (SiBCS, USDA, future modules) inherits the protection.

Usage

```
plaggic(
  pedon,
  min_thickness = 20,
  max_bd = 1.5,
  min_oc = 0.6,
  min_p_mehlich3 = 50
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).
`max_bd`	Numeric threshold or option (see Details).
`min_oc`	Numeric threshold or option (see Details).
`min_p_mehlich3`	Numeric threshold or option (see Details).

planic_features — *Planic features (WRB 2022)*

Description

Tests whether the profile shows an abrupt textural change between adjacent horizons (clay-doubling within 7.5 cm vertical distance, typically at the E/Bt boundary). Diagnostic of Planosols.

Usage

```
planic_features(pedon, min_ratio = 2, require_abrupt_boundary = TRUE)
```

Arguments

- `pedon` — A `PedonRecord`.
- `min_ratio` — Minimum clay ratio (default 2.0).
- `require_abrupt_boundary` — If TRUE (default), the upper horizon must have `boundary_distinctness` matching "abrupt".

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Planosols.

planosol — *Planosol RSG gate (WRB 2022 Ch 4, p 107)*

Description

WRB-canonical: abrupt textural difference \<= 75 cm AND, in 5 cm directly above or below the abrupt textural difference, stagnic properties (>= 50% redoximorphic features) AND reducing conditions.

Usage

```
planosol(pedon)
```

Arguments

- `pedon` — A `PedonRecord`.

Details

v0.3.4 enforces all three components. The 5-cm-window restriction is relaxed to "the layer immediately above or below the abrupt textural difference satisfies stagnic + reducing".

`planossolo` *Planossolos (SiBCS Cap 4, p 112; conceito Cap 3, p 101-102)*

Description

Horizonte B planico nao coincidente com plintico (sem carater sodico), imediatamente abaixo de A ou E.

Usage

```
planossolo(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`planossolo_haplico` *Planossolos Haplicos (catch-all).*

Description

Planossolos Haplicos (catch-all).

Usage

```
planossolo_haplico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`planossolo_natrico` *Planossolos Natricos (Cap 15): caracter sodico em \< 100 cm.*

Description

Planossolos Natricos (Cap 15): caracter sodico em \< 100 cm.

Usage

```
planossolo_natrico(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`plinthaquox_qualifying_usda` *Plinthaquox qualifying helper (Aquox: continuous plinthite phase) Pass when plinthite >= 50% in some 10+ cm layer (continuous phase proxy).*

Description

Plinthaquox qualifying helper (Aquox: continuous plinthite phase) Pass when plinthite >= 50% in some 10+ cm layer (continuous phase proxy).

Usage

```
plinthaquox_qualifying_usda(pedon, max_top_cm = 125)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

plinthic *Plinthic horizon (WRB 2022)*

Description

Tests whether any horizon meets the plinthic horizon criteria. Plinthite is Fe-rich material that hardens irreversibly on repeated wetting and drying; the plinthic horizon is the diagnostic of Plinthosols.

Usage

```
plinthic(pedon, min_thickness = 15, min_plinthite_pct = 15)
```

Arguments

pedon	A PedonRecord.
min_thickness	Minimum thickness in cm (default 15).
min_plinthite_pct	Minimum volume % plinthite (default 15).

Details

Sub-tests:

- `test_plinthite_concentration` – plinthite volume % >= 15
- `test_minimum_thickness` – thickness >= 15 cm

v0.2 limitations: WRB 2022 also accepts profiles with >= 40% red Fe-rich mottles as alternative criterion – not yet wired. The "irreversibly hardens" criterion is conceptual and requires field observation; v0.2 takes `plinthite_pct` as already representing true plinthite (as opposed to soft mottles).

Value

A `DiagnosticResult`.

v0.9.72 designation morphological inference (opt-in)

Field-described Brazilian Plintossolos profiles (e.g.\ the Embrapa Redape curated dataset) routinely encode plinthite via the designation suffix `f` in the master letter sequence (e.g.\ `Btf`, `2Btf`, `Cf`) – the curator's direct assertion that plinthite is present – without recording `plinthite_pct` as a numeric volume percent.

With `options(soilKey.plinthic_designation_inference = TRUE)` the function accepts a layer as plinthic when:

1. the canonical `plinthite_pct` test is `NA` for that layer, AND
2. the designation matches `[A-Z]+[A-Za-z]*f[0-9]?` (a `f` master-letter modifier in any sub-position).

Default is `FALSE` (canonical behaviour preserved).

References

IUSS Working Group WRB (2022), Chapter 3, Plinthic horizon.

`plinthic_subgroup_usda` *Plinthic Subgroup helper (Oxisols) Pass when plinthite >= 5% in any horizon within 125 cm.*

Description

Plinthic Subgroup helper (Oxisols) Pass when plinthite >= 5% in any horizon within 125 cm.

Usage

```
plinthic_subgroup_usda(pedon, max_top_cm = 125)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`plinth_subgroup_usda` *Plinth qualifying helper (Plinth*ults) Pass when plinthite >= 5% in 50%+ of layers within 150 cm.*

Description

Plinth qualifying helper (Plinth*ults) Pass when plinthite >= 5% in 50%+ of layers within 150 cm.

Usage

```
plinth_subgroup_usda(pedon, max_top_cm = 150)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`plintossolo` *Plintossolos (SiBCS Cap 4, p 113; conceito Cap 3, p 102-104)*

Description

Horizonte plintico (nao coincidente com B planico de carater sodico), OR litoplintico, OR concrecionario, iniciando dentro de 40 cm OR dentro de 200 cm precedido de glei OR A/E OR horizonte com cores palidas / variegadas / mosqueados.

Usage

```
plintossolo(pedon)
```

Arguments

pedon	A PedonRecord.

`plintossolo_argiluvico` *Plintossolos Argiluvicos (Cap 16): horizonte plintico + B textural OR carater argiluvico.*

Description

Plintossolos Argiluvicos (Cap 16): horizonte plintico + B textural OR carater argiluvico.

Usage

```
plintossolo_argiluvico(pedon)
```

Arguments

pedon	A PedonRecord.

plintossolo_haplico *Plintossolos Haplicos (catch-all).*

Description

Plintossolos Haplicos (catch-all).

Usage

```
plintossolo_haplico(pedon)
```

Arguments

pedon	A PedonRecord.

plintossolo_petrico *Plintossolos Petricos (Cap 16): horizonte concrecionario OR litoplintico (sem horizonte plintico precedendo).*

Description

Plintossolos Petricos (Cap 16): horizonte concrecionario OR litoplintico (sem horizonte plintico precedendo).

Usage

```
plintossolo_petrico(pedon)
```

Arguments

pedon	A PedonRecord.

`posterior_classify` *Bayesian posterior classifier (optional)*

Description

Combines a deterministic `ClassificationResult` with a spatial prior. The deterministic key remains authoritative – this function reports only an alternative probabilistic view useful for downstream uncertainty quantification.

Usage

```
posterior_classify(result, prior, epsilon = 0.001)
```

Arguments

`result`	A `ClassificationResult` from `classify_wrb2022`.
`prior`	A spatial-prior data.table (as returned by `spatial_prior`).
`epsilon`	Small smoothing constant added to all prior entries before normalising, so RSGs unseen by the prior do not receive zero posterior.

Details

Posterior is computed under the simple model:

$$P(rsg|site, evidence) \propto L(rsg|evidence) \times P(rsg|site)$$

where the likelihood `L` is concentrated on the deterministic assignment (delta-1 at that code) by default, optionally smoothed if `key_passed_others` is supplied.

Value

A `data.table` with columns `rsg_code`, `prior`, `likelihood`, `posterior`.

`predict.soilKey_pls_model`
Predict from a soilKey_pls_model

Description

S3 method that applies a trained PLSR model from `train_pls_from_ossl` to a (pre-processed) numeric matrix and returns predictions plus a 95 built from the cross-validated training RMSE.

Usage

```
## S3 method for class 'soilKey_pls_model'
predict(object, X, ...)
```

Arguments

`object`	A `soilKey_pls_model` object.
`X`	A pre-processed numeric matrix (rows = samples, columns = wavelengths). Must have the same column count used at training time.
`...`	Reserved.

Value

A data.frame with columns `value`, `pi95_low`, `pi95_high`, one row per sample.

`predict_from_spectra` *Predict soil properties from spectra*

Description

Ergonomic, named entry point for the OSSL-backed predictive pipeline. Accepts either a `PedonRecord` or a numeric spectra matrix, applies the same preprocessing used at training time (recorded on each model), and returns predictions in the canonical long-form schema.

Usage

```
predict_from_spectra(
  pedon_or_spectra,
  models = NULL,
  properties = NULL,
  overwrite = FALSE,
  verbose = TRUE,
  ...
)
```

Arguments

`pedon_or_spectra`	A `PedonRecord` (predictions merged into the pedon) OR a numeric matrix / vector of raw Vis-NIR spectra (rows = horizons, columns = wavelengths).
`models`	A named list of `soilKey_pls_model` objects (output of `train_pls_from_ossl`). Required.
`properties`	Character vector of property names to predict. Defaults to all properties in `models`.
`overwrite`	Passed to `fill_from_spectra` when `pedon_or_spectra` is a PedonRecord.
`verbose`	Verbosity passed downstream.
`...`	Ignored (reserved for future backends).

Details

When pedon_or_spectra is a PedonRecord, this function delegates to fill_from_spectra with method = "pretrained" and the predictions are written back to the pedon (with source = "predicted_spectra" provenance). When pedon_or_spectra is a numeric matrix or vector, this function returns the prediction data.table directly without touching any pedon.

Value

Either the mutated PedonRecord (invisibly) or a data.table with columns horizon_idx, property, value, pi95_low, pi95_high, n_neighbors.

Examples

```
if (requireNamespace("pls", quietly = TRUE)) {
  data(ossl_demo_sa)
  models <- try(train_pls_from_ossl(ossl_demo_sa,
                                    properties = c("clay_pct", "ph_h2o"),
                                    min_n = 10L,
                                    validation = "none"),
                silent = TRUE)
  # Prediction step needs a synthetic pedon with spectra attached.
  # predict_from_spectra(my_pedon, models = models)
}
```

---

predict_lab_from_spectra

Predict CIE Lab from Vis-NIR reflectance spectra

Description

Convenience wrapper: predict_xyz_from_spectra followed by the standard CIE Lab transform under D65 / 2-degree observer.

Usage

```
predict_lab_from_spectra(spectra, wavelengths)
```

Arguments

spectra	Reflectance values, in 0..1 or 0..100. A numeric vector (one sample), a numeric matrix (rows = samples, cols = wavelengths) or a data.frame.
wavelengths	Numeric vector of the wavelengths (in nm) corresponding to the columns of spectra. Must cover at least 400-700 nm; values outside 380-780 are ignored.

Value

A data.frame with columns L, a, b.

predict_munsell_from_spectra
Predict Munsell hue / value / chroma from Vis-NIR reflectance spectra

Description

Combines predict_xyz_from_spectra with the Munsell renotation interpolation in **munsellinterpol** (CRAN, GPL). Returns hue (e.g. "7.5YR"), value (0..10) and chroma (0..20) per sample, plus the soilKey fields munsell_hue_moist, munsell_value_moist, munsell_chroma_moist ready to write into a PedonRecord via the pedon's add_measurement method (see also fill_munsell_from_spectra).

Usage

```
predict_munsell_from_spectra(spectra, wavelengths, round_chip = TRUE)
```

Arguments

spectra	Reflectance values, in 0..1 or 0..100. A numeric vector (one sample), a numeric matrix (rows = samples, cols = wavelengths) or a data.frame.
wavelengths	Numeric vector of the wavelengths (in nm) corresponding to the columns of spectra. Must cover at least 400-700 nm; values outside 380-780 are ignored.
round_chip	If TRUE (default), snaps the predicted HVC to the nearest standard Munsell chip grid via munsellinterpol::roundHVC(). FALSE returns continuous HVC (useful for further numeric work).

Details

This is the v0.9.47 unblock for the v0.9.35 Argissolo Vermelho / Amarelo / Vermelho-Amarelo color-confusion case: when a user has Vis-NIR spectra (which Embrapa's BDsolos / FEBR do not include but the OSSL does), the Munsell hue can be recovered physically without waiting for the surveyor's morphological description.

Value

A data.frame with columns munsell_hue_moist, munsell_value_moist, munsell_chroma_moist, munsell_string (e.g. "7.5YR 4/6"), X, Y, Z, one row per sample.

Examples

```
if (requireNamespace("munsellinterpol", quietly = TRUE)) {
  # White reflector across the visible: should map to a near-neutral
  # high-value Munsell color.
  wl <- seq(380, 780, by = 5)
  R  <- rep(0.9, length(wl))
  predict_munsell_from_spectra(R, wavelengths = wl)
}
```

predict_ossl_mbl *Memory-based learning prediction against the OSSL library*

Description

Predicts a set of soil properties from pre-processed Vis-NIR or MIR spectra using *memory-based learning* (MBL) – the recommended OSSL workflow for heterogeneous libraries. Defaults follow the literature (Ramirez-Lopez et al., 2013): `k = 100` neighbours, PLS-score dissimilarity, local PLS regression with 5 components, internal leave-one-out validation.

Usage

```
predict_ossl_mbl(
  X,
  properties,
  region = "global",
  k = 100L,
  ossl_library = NULL,
  ...
)
```

Arguments

X	A pre-processed numeric matrix (rows = horizons, columns = wavelengths).
properties	Character vector of OSSL-supported property names.
region	One of "global", "south_america", "north_america", "europe", "africa".
k	Integer number of neighbours.
ossl_library	Optional list with the OSSL training spectra (Xr) and reference values (Yr, a data.frame keyed by properties). When NULL, the synthetic path is used.
...	Additional arguments forwarded to resemble::mbl.

Details

If `resemble::mbl` is installed and an `ossl_library` artefact is supplied (a list with elements `Xr`, `Yr`) the function delegates to `resemble::mbl()`; otherwise it returns a deterministic synthetic prediction conditioned on the input spectra so that downstream code, tests and vignettes run without external dependencies. The fallback is annotated via the `notes` attribute on the returned data.table.

Value

A data.table with columns `horizon_idx`, `property`, `value`, `pi95_low`, `pi95_high`, `n_neighbors`. The `"backend"` attribute records which path was taken (`"resemble"` or `"synthetic"`).

References

Ramirez-Lopez, L., Behrens, T., Schmidt, K., Stevens, A., Demattê, J. A. M., & Scholten, T. (2013). The spectrum-based learner: A new local approach for modeling soil Vis-NIR spectra of complex datasets. *Geoderma*, 195–196, 268–279.

`predict_ossl_plsr_local` *Local PLSR prediction against the OSSL library*

Description

Selects the `k` nearest neighbours to each test spectrum in the OSSL training set and fits a local PLS regression. Like `predict_ossl_mbl`, this function dispatches to `resemble::mbl` (with a `local_algorithm = "pls"` setting) when the dependency is available; otherwise it falls back to the synthetic predictor.

Usage

```
predict_ossl_plsr_local(
  X,
  properties,
  region = "global",
  k = 100L,
  ossl_library = NULL,
  ...
)
```

Arguments

`X`	A pre-processed numeric matrix (rows = horizons, columns = wavelengths).
`properties`	Character vector of OSSL-supported property names.
`region`	One of `"global"`, `"south_america"`, `"north_america"`, `"europe"`, `"africa"`.
`k`	Integer number of neighbours.
`ossl_library`	Optional list with the OSSL training spectra (`Xr`) and reference values (`Yr`, a data.frame keyed by `properties`). When `NULL`, the synthetic path is used.
`...`	Additional arguments forwarded to `resemble::mbl`.

Value

A data.table with the same schema as `predict_ossl_mbl`.

---

predict_ossl_pretrained
Pre-trained OSSL prediction

Description

Applies the OSSL-distributed pre-trained PLSR / Cubist models for a set of soil properties to pre-processed spectra. Pre-trained models are loaded from `ossl_models`, a named list of property models that each must implement a `predict(model, X)` interface returning a data.frame with columns `value`, `pi95_low`, `pi95_high`. When `ossl_models` is `NULL`, the synthetic predictor is used.

Usage

```
predict_ossl_pretrained(
  X,
  properties,
  region = "global",
  ossl_models = NULL,
  ...
)
```

Arguments

`X`	A pre-processed numeric matrix (rows = horizons, columns = wavelengths).
`properties`	Character vector of OSSL-supported property names.
`region`	One of `"global"`, `"south_america"`, `"north_america"`, `"europe"`, `"africa"`.
`ossl_models`	Optional named list of pre-trained models, keyed by property name.
`...`	Reserved.

Value

A data.table with columns `horizon_idx`, `property`, `value`, `pi95_low`, `pi95_high`, `n_neighbors`. `n_neighbors` is `NA_integer_` for pre-trained models. The `"backend"` attribute records which path was taken.

---

predict_xyz_from_spectra
Predict CIE XYZ tristimulus values from Vis-NIR reflectance spectra

---

Description

Numerically integrates user reflectance against the CIE 1931 2-degree Standard Observer color-matching functions, weighted by the D65 illuminant. Returns the tristimulus values X, Y, Z on the standard scale where $Y = 100$ for a perfect diffuse white.

Usage

```
predict_xyz_from_spectra(spectra, wavelengths)
```

Arguments

spectra	Reflectance values, in 0..1 or 0..100. A numeric vector (one sample), a numeric matrix (rows = samples, cols = wavelengths) or a data.frame.
wavelengths	Numeric vector of the wavelengths (in nm) corresponding to the columns of `spectra`. Must cover at least 400-700 nm; values outside 380-780 are ignored.

Value

A data.frame with columns `X`, `Y`, `Z`, one row per sample.

See Also

`predict_lab_from_spectra`, `predict_munsell_from_spectra`.

`preprocess_spectra` *Pre-process Vis-NIR or MIR spectra*

Description

Applies a chosen pre-processing pipeline to a numeric matrix of soil spectra. Rows are samples (typically horizons) and columns are wavelengths. Returns a numeric matrix; SG-based methods shorten the spectrum by `w - 1` columns at the edges (default `w = 5` so two columns are dropped from each side).

Usage

```
preprocess_spectra(X, method = c("snv+sg1", "snv", "sg1"), w = 5L, p = 2L)
```

Arguments

X	Numeric matrix or data.frame of spectra (rows = samples, columns = wavelengths). Wavelengths should be evenly spaced.
method	One of `"snv"`, `"sg1"`, `"snv+sg1"`. Default `"snv+sg1"`.
w	Window size for the SG filter. Must be odd; default 5.
p	Polynomial order for the SG filter. Default 2.

Details

Supported `method` values:

- `"snv"` Standard Normal Variate. Each row is centered on its own mean and divided by its own standard deviation.
- `"sg1"` Savitzky-Golay 1st derivative with a window of five wavelengths and a quadratic polynomial.
- `"snv+sg1"` SNV followed by SG1 (default; the standard pipeline used by OSSL pretrained models for Vis-NIR).

If `prospectr` is available, we use `prospectr::standardNormalVariate` and `prospectr::savitzkyGolay` (Rcpp implementation, faster and supports arbitrary window/polynomial). The native fallback uses the classical 5-point first-derivative coefficients `(-2, -1, 0, 1, 2) / 10`, which is the closed-form Savitzky-Golay solution for window 5 / polynomial 2 / derivative 1.

Value

A numeric matrix. Column names (wavelengths) are preserved where possible; SG trimming drops `(w - 1) / 2` columns from each edge.

References

Savitzky, A., & Golay, M. J. E. (1964). Smoothing and differentiation of data by simplified least squares procedures. *Analytical Chemistry*, 36(8), 1627–1639.

Barnes, R. J., Dhanoa, M. S., & Lister, S. J. (1989). Standard Normal Variate transformation and de-trending of near-infrared diffuse reflectance spectra. *Applied Spectroscopy*, 43(5), 772–777.

Stevens, A., & Ramirez-Lopez, L. (2024). *prospectr*: Misc. functions for processing and sample selection of spectroscopic data. R package version 0.2.7.

Examples

```
set.seed(1)
X <- matrix(runif(5 * 2151, 0, 1), nrow = 5)
colnames(X) <- 350:2500
Xp <- preprocess_spectra(X, method = "snv+sg1")
dim(Xp)  # 5 x 2147 (4 columns dropped by SG window 5)
```

`pretic` *Pretic horizon (WRB 2022): "Amazonian Dark Earth" (terra preta de indio) horizon – thick anthropogenic surface with high P, SOC, and incorporated charcoal / pottery.*

Description

Pretic horizon (WRB 2022): "Amazonian Dark Earth" (terra preta de indio) horizon – thick anthropogenic surface with high P, SOC, and incorporated charcoal / pottery.

Usage

```
pretic(pedon, min_thickness = 20, min_oc = 1.5, min_p_mehlich3 = 30)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
min_oc	Numeric threshold or option (see Details).
min_p_mehlich3	Numeric threshold or option (see Details).

---

print.soilKey_pls_model

Print method for soilKey_pls_model

Description

Print method for soilKey_pls_model

Usage

```
## S3 method for class 'soilKey_pls_model'
print(x, ...)
```

Arguments

x	A soilKey_pls_model object.
...	Reserved.

Value

The object, invisibly.

---

prior_consistency_check

Check consistency between a deterministic RSG assignment and a spatial prior

---

Description

Returns a list describing whether the assigned RSG is plausible under the given prior. The deterministic classification is never overridden – this is purely a sanity-check signal.

Usage

```
prior_consistency_check(rsg_code, prior, threshold = 0.01)
```

Arguments

rsg_code	Two-letter RSG code (e.g. "FR"). Either the rsg_or_order from a ClassificationResult (in which case it must be the RSG name; we try to translate via the trace) or the bare code from a key trace entry.
prior	A spatial-prior data.table from spatial_prior.
threshold	Probability below which an assignment is flagged inconsistent (default 0.01).

Value

A list with elements:

- consistent: TRUE / FALSE / NA.
- p: probability of the assigned RSG in the prior (or NA_real_ if not found).
- threshold: the threshold used.
- status: a short status string – "consistent", "inconsistent", or "no_data".
- note: human-readable explanation.
- top_prior: data.table with the top three classes from the prior (for messages).

---

protocalcic_properties

Protocalcic properties (WRB 2022 Ch 3.2.8)

Description

Visible secondary carbonate accumulations, less than the calcic gate. Detects via caco3_pct between 0.5 and the calcic threshold (15) AND designation effervescence pattern (k).

Usage

```
protocalcic_properties(pedon, min_caco3_pct = 0.5, max_caco3_pct = 15)
```

Arguments

pedon	A PedonRecord.
min_caco3_pct	Numeric threshold or option (see Details).
max_caco3_pct	Numeric threshold or option (see Details).

`protogypsic_properties` *Protogypsic properties (WRB 2022 Ch 3.2.9): visible secondary gypsum \>= 1% but below the gypsic gate.*

Description

Protogypsic properties (WRB 2022 Ch 3.2.9): visible secondary gypsum \>= 1% but below the gypsic gate.

Usage

```
protogypsic_properties(pedon, min_caso4_pct = 1, max_caso4_pct = 5)
```

Arguments

`pedon`	A `PedonRecord`.
`min_caso4_pct`	Numeric threshold or option (see Details).
`max_caso4_pct`	Numeric threshold or option (see Details).

`protovertic` *Protovertic horizon (WRB 2022 Ch 3.1)*

Description

A weakly developed vertic horizon – the swelling/shrinking machinery is present but does not reach the full vertic intensity (cracks too narrow, or slickensides only "few", or thickness too small). Used by the Protovertic qualifier; relevant for soils that would be Vertisols if the cracks/slickensides were a notch stronger.

Usage

```
protovertic(pedon, min_clay = 30, min_thickness = 15)
```

Arguments

`pedon`	A `PedonRecord`.
`min_clay`	Numeric threshold or option (see Details).
`min_thickness`	Numeric threshold or option (see Details).

Details

v0.3.5 detection: clay \>= 30% AND any positive vertic evidence (slickensides at \>= "few" OR cracks_width_cm \>= 0.2 OR a wedge/lenticular structure_type) AND thickness \>= 15 cm. The positive cases that pass the strict `vertic_horizon` test are explicitly excluded so the two diagnostics partition the vertic-spectrum cleanly.

psammentic_subgroup_usda
Psammentic Subgroup helper (Aquorthels)

Description

Pass when, in particle-size control section: < 35% rock fragments AND texture class loamy fine sand or coarser in all layers.

Usage

```
psammentic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

psamment_qualifying_usda
*Psamment Suborder qualifier (sandy texture: clay + 2*silt < 30 AND no clay films / argillic).*

Description

Psamment Suborder qualifier (sandy texture: clay + 2*silt < 30 AND no clay films / argillic).

Usage

```
psamment_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_abruptic` *Abruptic qualifier (ap): abrupt textural difference within 100 cm.*

Description

Abruptic qualifier (ap): abrupt textural difference within 100 cm.

Usage

```
qual_abruptic(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_aceric` *Aceric qualifier (ae): pH (1:1 H2O) <= 5 in some layer within the upper 50 cm. Used for sub-aerially exposed acid-sulfate soils (Solonchaks, Gleysols on former tidal flats). v0.9.1: numeric pH gate only; v0.9.2 adds the cross-check against `thionic` / sulfidic material to disambiguate from naturally acidic Histosols.*

Description

Aceric qualifier (ae): pH (1:1 H2O) <= 5 in some layer within the upper 50 cm. Used for sub-aerially exposed acid-sulfate soils (Solonchaks, Gleysols on former tidal flats). v0.9.1: numeric pH gate only; v0.9.2 adds the cross-check against `thionic` / sulfidic material to disambiguate from naturally acidic Histosols.

Usage

```
qual_aceric(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_acric` *Acric qualifier (ac): argic horizon + low CEC + high Al. v0.9: argic + CEC < 24 cmolc/kg clay + exch Al > Ca+Mg+K+Na.*

Description

Acric qualifier (ac): argic horizon + low CEC + high Al. v0.9: argic + CEC < 24 cmolc/kg clay + exch Al > Ca+Mg+K+Na.

Usage

```
qual_acric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_acroxic` *Acroxic qualifier (ax): andic + extremely low effective exchange complex (Ca + Mg + K + Na exch + 1 N KCl Al-exch <= 2 cmol+/kg fine earth) in some layer of the andic part within 100 cm.*

Description

Acroxic qualifier (ax): andic + extremely low effective exchange complex (Ca + Mg + K + Na exch + 1 N KCl Al-exch <= 2 cmol+/kg fine earth) in some layer of the andic part within 100 cm.

Usage

```
qual_acroxic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_activic`	*Activic supplementary qualifier (av): active aluminium >= 5 cmol/kg WRB 2022 Ch 5: "KCl-extractable Al (`al_kcl_cmol`) >= 5 cmol(c)/kg in any layer in upper 100 cm." Proxy via existing `al_cmol` (exchangeable Al) when al_kcl_cmol absent.*

Description

Activic supplementary qualifier (av): active aluminium >= 5 cmol/kg WRB 2022 Ch 5: "KCl-extractable Al (`al_kcl_cmol`) >= 5 cmol(c)/kg in any layer in upper 100 cm." Proxy via existing `al_cmol` (exchangeable Al) when al_kcl_cmol absent.

Usage

```
qual_activic(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_albic`	*Albic qualifier (ab): albic horizon <= 100 cm.*

Description

Albic qualifier (ab): albic horizon <= 100 cm.

Usage

```
qual_albic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_alcalic	*Alcalic supplementary qualifier (ac): pH (H2O) >= 9.0 WRB 2022 Ch 5: "Strongly alkaline reaction (pH H2O >= 9 in any layer within 100 cm of the soil surface)."*

Description

Alcalic supplementary qualifier (ac): pH (H2O) >= 9.0 WRB 2022 Ch 5: "Strongly alkaline reaction (pH H2O >= 9 in any layer within 100 cm of the soil surface)."

Usage

```
qual_alcalic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_alic	*Alic qualifier (al): argic + high CEC + high Al saturation.*

Description

Alic qualifier (al): argic + high CEC + high Al saturation.

Usage

```
qual_alic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_aluandic *Aluandic qualifier (aa): andic properties + Al-dominant active component (Al / (Al + 0.5 Si) >= 0.5 in mass).*

Description

Aluandic qualifier (aa): andic properties + Al-dominant active component (Al / (Al + 0.5 Si) >= 0.5 in mass).

Usage

```
qual_aluandic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_andic *Andic qualifier (an): andic OR vitric properties combined >= 30 cm. v0.9 simplification: passes if andic_properties or vitric_properties passes within 100 cm.*

Description

Andic qualifier (an): andic OR vitric properties combined >= 30 cm. v0.9 simplification: passes if andic_properties or vitric_properties passes within 100 cm.

Usage

```
qual_andic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_anofluvic — *Anofluvic qualifier (af): fluvic material only at depth >= 50 cm*

Description

WRB 2022 Ch 5 (Fluvisols): "Fluvic material starting >= 50 cm from the soil surface." Depth modifier of `fluvic_material`.

Usage

```
qual_anofluvic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_anthraquic — *Anthraquic qualifier (aq): anthraquic horizon (puddled-rice surface).*

Description

Anthraquic qualifier (aq): anthraquic horizon (puddled-rice surface).

Usage

```
qual_anthraquic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_anthric — *Anthric qualifier (ak): anthric properties.*

Description

Anthric qualifier (ak): anthric properties.

Usage

```
qual_anthric(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_anthromollic — *Anthromollic qualifier (am): anthric horizon overlying spodic*

Description

WRB 2022 Ch 5 (Podzols): "Having an anthric (irrigation / Plaggic-like) surface horizon directly over spodic / albic / diagnostic horizon." Combines anthric_horizons + overlying-spodic check.

Usage

```
qual_anthromollic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_archaic — *Archaic supplementary qualifier (ah): archeological context*

Description

WRB 2022 Ch 5: "Soil developed in or affected by ancient cultural material (>1000 yr old)." Detects via contamination_type matching "archaeological" or site-level cultural-period field.

Usage

```
qual_archaic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_arenic — *Arenic qualifier (ar): texture sand or loamy sand >= 30 cm in <= 100 cm.*

Description

Arenic qualifier (ar): texture sand or loamy sand >= 30 cm in <= 100 cm.

Usage

```
qual_arenic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_arenicolic` *Arenicolic supplementary qualifier (an): faunal sand burrows*

Description

WRB 2022 Ch 5: "Containing layers with extensive sand-grade bioturbation (faunal burrows from earthworms / ants / termites)." Implementation: `bioturbation_density` \>= "common".

Usage

```
qual_arenicolic(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_aric` *Aric qualifier (ar): mineral surface horizon homogenised by ploughing – designation pattern `Ap`, `Apk`, `Apc`, etc., starting within the upper 30 cm.*

Description

Aric qualifier (ar): mineral surface horizon homogenised by ploughing – designation pattern `Ap`, `Apk`, `Apc`, etc., starting within the upper 30 cm.

Usage

```
qual_aric(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_bathyspodic` *Bathyspodic supplementary qualifier (bs): spodic at 100-200 cm depth*

Description

Bathyspodic supplementary qualifier (bs): spodic at 100-200 cm depth

Usage

```
qual_bathyspodic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_biocrustic` *Biocrustic supplementary qualifier (bk): biological soil crust*

Description

WRB 2022 Ch 5: "Surface biological crust (cyanobacteria, algae, lichens, mosses)." Implementation: `surface_crust_type` matching biological pattern in upper 5 cm.

Usage

```
qual_biocrustic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_brunic` *Brunic qualifier (br):* incipient-only *subsurface alteration – cambic horizon within the upper 100 cm AND no argic, spodic, ferralic, or nitic horizon present. Used by WRB 2022 Ch 4 for Arenosols that have begun to develop a weak Bw without crossing into Cambisol / Acrisol / Lixisol / Ferralsol territory; in those RSGs the cambic alone is the gating diagnostic and Brunic would be redundant.*

Description

Brunic qualifier (br): *incipient-only* subsurface alteration – cambic horizon within the upper 100 cm AND no argic, spodic, ferralic, or nitic horizon present. Used by WRB 2022 Ch 4 for Arenosols that have begun to develop a weak Bw without crossing into Cambisol / Acrisol / Lixisol / Ferralsol territory; in those RSGs the cambic alone is the gating diagnostic and Brunic would be redundant.

Usage

```
qual_brunic(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_bryic   *Bryic supplementary qualifier (by): bryophyte cover at surface*

Description

WRB 2022 Ch 5: "Predominant bryophyte (moss / liverwort) ground cover." Implementation: `layer_origin` matches moss / lichen pattern OR `vegetation_cover` site field >= 50.

Usage

```
qual_bryic(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_calcaric   *Calcaric qualifier (cl): calcaric material >= 25 cm in upper 100 cm.*

Description

Calcaric qualifier (cl): calcaric material >= 25 cm in upper 100 cm.

Usage

```
qual_calcaric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_calcic *Calcic qualifier (cc): calcic horizon <= 100 cm.*

Description

Calcic qualifier (cc): calcic horizon <= 100 cm.

Usage

```
qual_calcic(pedon)
```

Arguments

pedon A PedonRecord.

qual_cambic *Cambic qualifier (cm): cambic horizon <= 50 cm.*

Description

Cambic qualifier (cm): cambic horizon <= 50 cm.

Usage

```
qual_cambic(pedon)
```

Arguments

pedon A PedonRecord.

qual_capillaric *Capillaric supplementary qualifier (cp): capillary rise zone WRB 2022 Ch 5: "Capillary rise from a shallow water table to within 50 cm of the soil surface; flagged via redox concentrations (>=2%) + fine texture (clay+silt > 50%)."*

Description

Capillaric supplementary qualifier (cp): capillary rise zone WRB 2022 Ch 5: "Capillary rise from a shallow water table to within 50 cm of the soil surface; flagged via redox concentrations (>=2%) + fine texture (clay+silt > 50%)."

Usage

```
qual_capillaric(pedon)
```

Arguments

pedon A PedonRecord.

---

qual_carbic *Carbic qualifier (cb): spodic horizon dominated by humus illuviation. v0.9.1: spodic + OC >= 6% in some spodic layer (the WRB threshold for Carbic / "humus-Podzol" expression).*

Description

Carbic qualifier (cb): spodic horizon dominated by humus illuviation. v0.9.1: spodic + OC >= 6% in some spodic layer (the WRB threshold for Carbic / "humus-Podzol" expression).

Usage

```
qual_carbic(pedon)
```

Arguments

pedon A PedonRecord.

---

qual_carbonatic *Carbonatic supplementary qualifier (cn): >= 50% carbonates*

Description

Carbonatic supplementary qualifier (cn): >= 50% carbonates

Usage

```
qual_carbonatic(pedon)
```

Arguments

pedon A PedonRecord.

qual_carbonic — *Carbonic supplementary qualifier (cb): high SOC content (>= 6%)*

Description

Carbonic supplementary qualifier (cb): high SOC content (>= 6%)

Usage

```
qual_carbonic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_chernic — *Chernic qualifier (ch): chernic horizon (intensely worm-mixed mollic-like) within 100 cm.*

Description

Chernic qualifier (ch): chernic horizon (intensely worm-mixed mollic-like) within 100 cm.

Usage

```
qual_chernic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_chloridic — *Chloridic supplementary qualifier (cl): high chloride WRB 2022 Ch 5: "Containing >= 4 cmol(c)/kg chloride OR EC >= 8 dS/m within 100 cm." Proxy via electrical conductivity field (`ec_ds_m`) when chloride is unavailable.*

Description

Chloridic supplementary qualifier (cl): high chloride WRB 2022 Ch 5: "Containing >= 4 cmol(c)/kg chloride OR EC >= 8 dS/m within 100 cm." Proxy via electrical conductivity field (`ec_ds_m`) when chloride is unavailable.

Usage

```
qual_chloridic(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_chromic	*Chromic qualifier (cr): hue redder than 7.5YR + chroma > 4 (in upper subsoil 25-150 cm).*

Description

Chromic qualifier (cr): hue redder than 7.5YR + chroma > 4 (in upper subsoil 25-150 cm).

Usage

```
qual_chromic(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_clayic	*Clayic qualifier (ce): clay >= 60% texture for a layer >= 30 cm in the upper 100 cm.*

Description

Clayic qualifier (ce): clay >= 60% texture for a layer >= 30 cm in the upper 100 cm.

Usage

```
qual_clayic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_coarsic *Coarsic qualifier (cr): >= 70% coarse fragments by volume in upper 100 cm*

Description

WRB 2022 Ch 5: "Containing layers (in total >= 30 cm thick) with >= 70% by volume coarse fragments and/or technic hard material averaged over a depth of 100 cm from the soil surface."

Usage

```
qual_coarsic(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Applies to: HISTOSOLS, TECHNOSOLS, CRYOSOLS, LEPTOSOLS, PODZOLS, PLINTHOSOLS, DURISOLS, GYPSISOLS, CALCISOLS.

Implementation: weighted mean of `coarse_fragments_pct` over the upper 100 cm; passes if \>= 70 (or NA if no measurements).

qual_cohesic *Cohesic supplementary qualifier (co): cohesive horizon (extra-firm dry) WRB 2022 Ch 5: "Containing layers with extreme dry consistence AND moist consistence very firm." Implementation: matches via* `consistence_dry` *("extremely hard") OR* `consistence_moist` *("very firm"), within 100 cm.*

Description

Cohesic supplementary qualifier (co): cohesive horizon (extra-firm dry) WRB 2022 Ch 5: "Containing layers with extreme dry consistence AND moist consistence very firm." Implementation: matches via `consistence_dry` ("extremely hard") OR `consistence_moist` ("very firm"), within 100 cm.

Usage

```
qual_cohesic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_columnic *Columnic supplementary qualifier (cm): columnar / prismatic structure WRB 2022 Ch 5: "Columnar or strong prismatic structure (associated with natric horizons)."*

Description

Columnic supplementary qualifier (cm): columnar / prismatic structure WRB 2022 Ch 5: "Columnar or strong prismatic structure (associated with natric horizons)."

Usage

```
qual_columnic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_cordic *Cordic supplementary qualifier (cd): cordic horizon*

Description

WRB 2022 Ch 5: "Cemented horizon NOT meeting duripan / petrocalcic / petrogypsic criteria but slacks moderately in water." Detection via `cordic_horizon` TRUE/FALSE schema flag.

Usage

```
qual_cordic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_cryic *Cryic qualifier (cy): cryic horizon <= 100 cm.*

Description

Cryic qualifier (cy): cryic horizon <= 100 cm.

Usage

```
qual_cryic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_cumulic *Cumulic qualifier (cu): a layer of recent depositional material added on top of an existing soil. v0.9.3.B proxy: `layer_origin` is fluvic / aeolic / solimovic at the top of the profile, OR the uppermost mineral horizon's designation matches `^[AC]u?\d?` (cumulic-style suffix).*

Description

Cumulic qualifier (cu): a layer of recent depositional material added on top of an existing soil. v0.9.3.B proxy: `layer_origin` is fluvic / aeolic / solimovic at the top of the profile, OR the uppermost mineral horizon's designation matches `^[AC]u?\d?` (cumulic-style suffix).

Usage

```
qual_cumulic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_cutanic *Cutanic qualifier (ct): visible illuvial clay coatings on argic- horizon ped surfaces (the "Cutanic Luvisol" / "Cutanic Argissol" signature). v0.9.1: argic horizon passes AND the schema column* `clay_films_amount` *contains "common", "many", or "continuous" (or "shiny" – common Brazilian descriptor for nitic surfaces) in some argic layer.*

Description

Cutanic qualifier (ct): visible illuvial clay coatings on argic- horizon ped surfaces (the "Cutanic Luvisol" / "Cutanic Argissol" signature). v0.9.1: argic horizon passes AND the schema column `clay_films_amount` contains "common", "many", or "continuous" (or "shiny" – common Brazilian descriptor for nitic surfaces) in some argic layer.

Usage

```
qual_cutanic(pedon)
```

Arguments

pedon	A `PedonRecord`.

---

qual_densic *Densic qualifier (dn): bulk density >= 1.8 g/cm3 in some root- restricting layer within 100 cm.*

Description

Densic qualifier (dn): bulk density >= 1.8 g/cm3 in some root- restricting layer within 100 cm.

Usage

```
qual_densic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_differentic *Differentic supplementary qualifier (df): contrasting layers WRB 2022 Ch 5: "Strong differences (texture, mineralogy, color) between adjacent layers without abrupt textural transition (mild clay-increase 1.2-1.4x ratio)."*

Description

Differentic supplementary qualifier (df): contrasting layers WRB 2022 Ch 5: "Strong differences (texture, mineralogy, color) between adjacent layers without abrupt textural transition (mild clay-increase 1.2-1.4x ratio)."

Usage

```
qual_differentic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_dolomitic *Dolomitic qualifier (do): dolomitic material in upper 100 cm.*

Description

Dolomitic qualifier (do): dolomitic material in upper 100 cm.

Usage

```
qual_dolomitic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_dorsic — *Dorsic supplementary qualifier (do): dorsal-ridge microrelief*

Description

Dorsic supplementary qualifier (do): dorsal-ridge microrelief

Usage

```
qual_dorsic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_drainic — *Drainic qualifier (dr): artificially drained organic soil. v0.9.1: site$drainage_class or site$land_use carries an explicit* artificial *drainage marker AND organic_material passes. Natural drainage classes (e.g. "very poorly drained", "well drained") do NOT trigger Drainic on their own.*

Description

Drainic qualifier (dr): artificially drained organic soil. v0.9.1: site$drainage_class or site$land_use carries an explicit *artificial* drainage marker AND organic_material passes. Natural drainage classes (e.g. "very poorly drained", "well drained") do NOT trigger Drainic on their own.

Usage

```
qual_drainic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_duric` *Duric qualifier (du): duric horizon <= 100 cm.*

Description

Duric qualifier (du): duric horizon <= 100 cm.

Usage

```
qual_duric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_dystric` *Dystric qualifier (dy): low base saturation throughout. v0.9: BS < 50% from 20 to 100 cm in mineral material.*

Description

Dystric qualifier (dy): low base saturation throughout. v0.9: BS < 50% from 20 to 100 cm in mineral material.

Usage

```
qual_dystric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_ekranic`	*Ekranic qualifier (ek): impervious cover (asphalt, concrete) starting within 5 cm of the surface. v0.9.1: technic_hard_material with top depth <= 5 cm.*

Description

Ekranic qualifier (ek): impervious cover (asphalt, concrete) starting within 5 cm of the surface. v0.9.1: technic_hard_material with top depth <= 5 cm.

Usage

```
qual_ekranic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_endic`	*Endic supplementary qualifier (ec): generic "in deep horizon" marker*

Description

WRB 2022 Ch 5: generic "Endo-X" prefix marker for any qualifier that takes a depth window 50-100 cm. Without a base diagnostic it returns NA; in practice it is composed with another qualifier.

Usage

```
qual_endic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_endoabruptic` *Endoabruptic supplementary qualifier (eea): abrupt textural change deep*

Description

Endoabruptic supplementary qualifier (eea): abrupt textural change deep

Usage

```
qual_endoabruptic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_endocalcaric` *Endocalcaric qualifier (cae): calcaric only at depth >= 50 cm*

Description

WRB 2022 Ch 5 (Umbrisols / Retisols): "Calcaric material starting >= 50 cm from the soil surface." Modifier of `calcaric_material`.

Usage

```
qual_endocalcaric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_endocalcic — *Endocalcic qualifier (cam): calcic horizon between 50 and 100 cm.*

Description

WRB 2022 Ch 5 (depth-conditional supplementary form of Calcic). Referenced in Chernozems Ch 4. The diagnostic is the same as Calcic; the difference is the depth band – Endocalcic requires the calcic horizon to start at >= 50 cm (deep, subsoil) rather than within the upper 50 cm.

Usage

```
qual_endocalcic(pedon)

qual_endocalcic(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

qual_endodolomitic — *Endodolomitic qualifier (dme): dolomitic only at depth >= 50 cm*

Description

WRB 2022 Ch 5 (Umbrisols / Retisols): "Dolomitic material starting >= 50 cm from the soil surface." Modifier of dolomitic_material.

Usage

```
qual_endodolomitic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_endoduric *Endoduric supplementary qualifier: duric horizon at depth >= 50 cm*

Description

Endoduric supplementary qualifier: duric horizon at depth >= 50 cm

Usage

```
qual_endoduric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_endodystric *Endodystric supplementary qualifier (eds): dystric only at depth*

Description

WRB 2022 Ch 5: "Distric (BS < 50%) at >= 50 cm depth."

Usage

```
qual_endodystric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_endoeutric *Endoeutric supplementary qualifier (eee): eutric only at depth*

Description

Endoeutric supplementary qualifier (eee): eutric only at depth

Usage

```
qual_endoeutric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_endogleyic` *Endogleyic qualifier (eng): gleyic conditions between 50 and 100 cm.*

Description

Endogleyic qualifier (eng): gleyic conditions between 50 and 100 cm.

Usage

```
qual_endogleyic(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`qual_endogypsic` *Endogypsic supplementary qualifier: gypsic horizon at depth >= 50 cm*

Description

Endogypsic supplementary qualifier: gypsic horizon at depth >= 50 cm

Usage

```
qual_endogypsic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_endoleptic — *Endoleptic supplementary qualifier (lle): rock contact 50-100 cm*

Description

Endoleptic supplementary qualifier (lle): rock contact 50-100 cm

Usage

```
qual_endoleptic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_endostagnic — *Endostagnic qualifier (ens): stagnic conditions between 50 and 100 cm.*

Description

Endostagnic qualifier (ens): stagnic conditions between 50 and 100 cm.

Usage

```
qual_endostagnic(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

qual_endothionic — *Endothionic supplementary qualifier (etn): thionic at depth >= 50 cm*

Description

Endothionic supplementary qualifier (etn): thionic at depth >= 50 cm

Usage

```
qual_endothionic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_endothyric — *Endothyric supplementary qualifier (etc): thyric only at depth >= 50*

Description

Endothyric supplementary qualifier (etc): thyric only at depth >= 50

Usage

```
qual_endothyric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_entic — *Entic qualifier (et): albic horizon AND NOT spodic*

Description

WRB 2022 Ch 5 (Podzols): "Having an albic horizon (>= 1 cm thick) starting <= 50 cm AND NOT meeting the criteria for a spodic horizon." Compose: albic AND NOT spodic.

Usage

```
qual_entic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_epic	*Epic supplementary qualifier (ep): generic "in shallow horizon"*

Description

Epic supplementary qualifier (ep): generic "in shallow horizon"

Usage

```
qual_epic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_epidystric	*Epidystric supplementary qualifier (epd): dystric only in upper 50 cm*

Description

WRB 2022 Ch 5: "Dystric (BS < 50%) in upper 50 cm and eutric below."

Usage

```
qual_epidystric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_epieutric	*Epieutric supplementary qualifier (eee): eutric only in upper 50 cm*

Description

Epieutric supplementary qualifier (eee): eutric only in upper 50 cm

Usage

```
qual_epieutric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_escalic` *Escalic supplementary qualifier (es): terraced / stepped morphology*

Description

Escalic supplementary qualifier (es): terraced / stepped morphology

Usage

```
qual_escalic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_eutric` *Eutric qualifier (eu): high base saturation. v0.9: BS >= 50% throughout 20-100 cm.*

Description

Eutric qualifier (eu): high base saturation. v0.9: BS >= 50% throughout 20-100 cm.

Usage

```
qual_eutric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_eutrosilic` *Eutrosilic qualifier (es): silandic + base saturation >= 50% in some layer of the silandic part within 100 cm.*

Description

Eutrosilic qualifier (es): silandic + base saturation >= 50% in some layer of the silandic part within 100 cm.

Usage

```
qual_eutrosilic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_evapocrustic *Evapocrustic supplementary qualifier (ev): evaporite surface crust*

Description

Evapocrustic supplementary qualifier (ev): evaporite surface crust

Usage

```
qual_evapocrustic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_ferralic *Ferralic qualifier (fl): ferralic horizon <= 150 cm.*

Description

Ferralic qualifier (fl): ferralic horizon <= 150 cm.

Usage

```
qual_ferralic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_ferric *Ferric qualifier (fr): ferric horizon <= 100 cm.*

Description

Ferric qualifier (fr): ferric horizon <= 100 cm.

Usage

```
qual_ferric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_ferritic` *Ferritic qualifier (fr): high free-Fe in fine earth*

Description

WRB 2022 Ch 5 (Nitisols / Ferralsols): "Containing layers with >= 18% Fe2O3 (or 12.6% Fe) in fine earth, averaged over upper 100 cm or to a contact / petroplinthic / pisoplinthic / R."

Usage

```
qual_ferritic(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation: weighted mean of `fe_dcb_pct` (DCB-extractable Fe2O3, the canonical Fe-pool for Ferralic / Nitic chemistry) over the upper 100 cm.

`qual_fibric` *Fibric qualifier (fi): organic material whose dominant decomposition class in the upper 100 cm is fibric (>= 2/3 fiber). v0.9.1: thickness-weighted dominance via Oi designation.*

Description

Fibric qualifier (fi): organic material whose dominant decomposition class in the upper 100 cm is fibric (>= 2/3 fiber). v0.9.1: thickness-weighted dominance via Oi designation.

Usage

```
qual_fibric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_floatic` *Floatic qualifier (fc): Histosol that floats on water.*

Description

WRB 2022 Ch 5 / Ch 4 Histosols (p 96): organic material with very low bulk density (< 0.1 g/cm3 dry, OR < 0.4 g/cm3 in fully saturated state) that floats on water. Practical proxy: oc_pct >= 12 (Histic threshold) AND bulk_density_g_cm3 <= 0.4 in any layer of the upper 100 cm.

Usage

```
qual_floatic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

A `DiagnosticResult`.

`qual_fluvic` *Fluvic qualifier (fv): fluvic material >= 25 cm thick starting <= 75 cm.*

Description

Fluvic qualifier (fv): fluvic material >= 25 cm thick starting <= 75 cm.

Usage

```
qual_fluvic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_folic` *Folic qualifier (fo): folic horizon at the soil surface. v0.9 delegates to histic_horizon with surface-only filter.*

Description

Folic qualifier (fo): folic horizon at the soil surface. v0.9 delegates to histic_horizon with surface-only filter.

Usage

```
qual_folic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_fractic` *Fractic qualifier (fc): fractures (cracks) within 100 cm*

Description

WRB 2022 Ch 5 (Durisols / Gypsisols / Calcisols): "Showing fractures within 100 cm of the soil surface" (a duripan, gypsic, or calcic horizon that has cracked / fractured).

Usage

```
qual_fractic(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation: positive `cracks_width_cm` or `cracks_depth_cm` on any layer with top <= 100 cm.

qual_garbic *Garbic qualifier (ga): >= 20% organic-waste artefacts (landfill refuse) in the upper 100 cm. v0.9.1 proxy: designation pattern (`Cgarb|garb|landfill|refuse`). Hard schema column `artefacts_garbic_pct` scheduled for v0.9.2.*

Description

Garbic qualifier (ga): >= 20% organic-waste artefacts (landfill refuse) in the upper 100 cm. v0.9.1 proxy: designation pattern (`Cgarb|garb|landfill|refuse`). Hard schema column `artefacts_garbic_pct` scheduled for v0.9.2.

Usage

```
qual_garbic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_gelic *Gelic supplementary qualifier (gl): permafrost or strong frost activity WRB 2022 Ch 5: "Permafrost within 200 cm of the soil surface OR gelic materials." Modifier of cryic_conditions for non-Cryosols.*

Description

Gelic supplementary qualifier (gl): permafrost or strong frost activity WRB 2022 Ch 5: "Permafrost within 200 cm of the soil surface OR gelic materials." Modifier of cryic_conditions for non-Cryosols.

Usage

```
qual_gelic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_gelistagnic` *Gelistagnic supplementary qualifier (gst): stagnic in cold conditions WRB 2022 Ch 5: "Stagnic features (perched water) in cryic regime." Compose: stagnic_pattern + cryic_conditions.*

Description

Gelistagnic supplementary qualifier (gst): stagnic in cold conditions WRB 2022 Ch 5: "Stagnic features (perched water) in cryic regime." Compose: stagnic_pattern + cryic_conditions.

Usage

```
qual_gelistagnic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_geoabruptic` *Geoabruptic supplementary qualifier (ga): abrupt change at lithological boundary WRB 2022 Ch 5: "Abrupt textural / mineralogical change at a lithological discontinuity (e.g., 2C horizon below B)." Implementation: designation pattern containing "2C" or "3C" (numeric prefix indicates lithologic discontinuity).*

Description

Geoabruptic supplementary qualifier (ga): abrupt change at lithological boundary WRB 2022 Ch 5: "Abrupt textural / mineralogical change at a lithological discontinuity (e.g., 2C horizon below B)." Implementation: designation pattern containing "2C" or "3C" (numeric prefix indicates lithologic discontinuity).

Usage

```
qual_geoabruptic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_geric	*Geric qualifier (gr): in some layer at <= 100 cm, the effective exchange complex (sum of bases + 1 N KCl Al-exchangeable) does not exceed 1.5 cmol+/kg fine earth, OR the soil shows net positive charge (delta pH = pH_KCl - pH_H2O > 0). The "or" path makes Geric / Posic overlap by design (per WRB Ch 5).*

Description

Geric qualifier (gr): in some layer at <= 100 cm, the effective exchange complex (sum of bases + 1 N KCl Al-exchangeable) does not exceed 1.5 cmol+/kg fine earth, OR the soil shows net positive charge (delta pH = pH_KCl - pH_H2O > 0). The "or" path makes Geric / Posic overlap by design (per WRB Ch 5).

Usage

```
qual_geric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_gibbsic	*Gibbsic qualifier (gi): high gibbsite (>= 25%) in fine earth*

Description

WRB 2022 Ch 5 (Plinthosols / Ferralsols): "Containing layers with >= 25% gibbsite by mass averaged over a depth of 100 cm".

Usage

```
qual_gibbsic(pedon)
```

Arguments

pedon	A PedonRecord.

Details

soilKey schema does not currently carry direct gibbsite percent. The closest proxy is `al_ox_pct` (oxalate-extractable Al, %), but gibbsite is poorly extracted by oxalate. The sulfuric attack `al2o3_sulfuric_pct` captures crystalline Al-oxides (gibbsite + boehmite + diaspore + Al-substitution in goethite). This implementation uses Al2O3 by sulfuric attack >= 25% as a proxy (slight over-estimate, since not all crystalline Al is gibbsite).

`qual_gilgaic`	*Gilgaic supplementary qualifier (gi): gilgai microrelief WRB 2022 Ch 5: "Gilgai microrelief (associated with vertic shrinking/swelling soils)." Site-level field detection.*

Description

Gilgaic supplementary qualifier (gi): gilgai microrelief WRB 2022 Ch 5: "Gilgai microrelief (associated with vertic shrinking/swelling soils)." Site-level field detection.

Usage

```
qual_gilgaic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_glacic`	*Glacic qualifier (gc): >= 75% ice by volume within 100 cm. v0.9.1 proxy: cryic conditions + designation pattern (`ice|gel|glac`). Schema column `ice_pct` scheduled for v0.9.2.*

Description

Glacic qualifier (gc): >= 75% ice by volume within 100 cm. v0.9.1 proxy: cryic conditions + designation pattern (`ice|gel|glac`). Schema column `ice_pct` scheduled for v0.9.2.

Usage

```
qual_glacic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_gleyic *Gleyic qualifier (gl): gleyic properties throughout a layer >= 25 cm starting <= 75 cm + reducing conditions.*

Description

Gleyic qualifier (gl): gleyic properties throughout a layer >= 25 cm starting <= 75 cm + reducing conditions.

Usage

```
qual_gleyic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_glossic *Glossic qualifier (gs): mollic horizon penetrated by albeluvic tongues (glossae). Diagnostic of Glossic Chernozems / Phaeozems on the steppe / forest-steppe transition.*

Description

Glossic qualifier (gs): mollic horizon penetrated by albeluvic tongues (glossae). Diagnostic of Glossic Chernozems / Phaeozems on the steppe / forest-steppe transition.

Usage

```
qual_glossic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_greyzemic` *Greyzemic qualifier (gz): mollic / umbric overlain by albic-like layer*

Description

WRB 2022 Ch 5 (Chernozems / Phaeozems / Umbrisols): "Having a mollic / umbric horizon overlain by a thin (<= 10 cm) albic-like layer with low chroma and high value (Munsell value >= 4 moist AND chroma <= 2)."

Usage

```
qual_greyzemic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Details

Implementation: presence of mollic OR umbric (we have `mollic` but not yet `umbric`) AND an overlying bleached layer (`munsell_value_moist` >= 4 and `munsell_chroma_moist` <= 2, thickness <= 10 cm).

`qual_grumic` *Grumic qualifier (gr): strong fine granular surface horizon (self-mulching Vertisol).*

Description

Grumic qualifier (gr): strong fine granular surface horizon (self-mulching Vertisol).

Usage

```
qual_grumic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_gypsic` *Gypsic qualifier (gy): gypsic horizon <= 100 cm.*

Description

Gypsic qualifier (gy): gypsic horizon <= 100 cm.

Usage

```
qual_gypsic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_gypsiric` *Gypsiric qualifier (gc): gypsiric material >= 25 cm in upper 100 cm.*

Description

Gypsiric qualifier (gc): gypsiric material >= 25 cm in upper 100 cm.

Usage

```
qual_gypsiric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_haplic` *Haplic qualifier (ha): no other principal qualifier of the RSG applies. Always passes; the qualifier resolution machinery uses it as the default when no other qualifier matched.*

Description

Haplic qualifier (ha): no other principal qualifier of the RSG applies. Always passes; the qualifier resolution machinery uses it as the default when no other qualifier matched.

Usage

```
qual_haplic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_hemic` *Hemic qualifier (hc): organic material whose dominant decomposition class in the upper 100 cm is hemic (1/6 - 2/3 fiber). v0.9.1: thickness-weighted dominance via Oe designation.*

Description

Hemic qualifier (hc): organic material whose dominant decomposition class in the upper 100 cm is hemic (1/6 - 2/3 fiber). v0.9.1: thickness-weighted dominance via Oe designation.

Usage

```
qual_hemic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_histic` *Histic qualifier (hi): histic horizon at or near the surface.*

Description

Histic qualifier (hi): histic horizon at or near the surface.

Usage

```
qual_histic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_hortic` *Hortic qualifier (ht): hortic horizon (long-cultivated dark surface).*

Description

Hortic qualifier (ht): hortic horizon (long-cultivated dark surface).

Usage

```
qual_hortic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_humic *Humic qualifier (hu): >= 1% SOC in upper 50 cm (weighted average).*

Description

Humic qualifier (hu): >= 1% SOC in upper 50 cm (weighted average).

Usage

```
qual_humic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_hydragric *Hydragric qualifier (hg): hydragric horizon (puddled-rice subsurface).*

Description

Hydragric qualifier (hg): hydragric horizon (puddled-rice subsurface).

Usage

```
qual_hydragric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_hydric *Hydric qualifier (hy): water content at 1500 kPa >= 100% (undried fine earth, WRB 2022). v0.9.1 accepts the air-dried equivalent (>= 70%) when the lab protocol pre-dries; the result is flagged as "potentially over-permissive" via the `notes` field when the value falls in the 70-100% band.*

Description

Hydric qualifier (hy): water content at 1500 kPa >= 100% (undried fine earth, WRB 2022). v0.9.1 accepts the air-dried equivalent (>= 70%) when the lab protocol pre-dries; the result is flagged as "potentially over-permissive" via the `notes` field when the value falls in the 70-100% band.

Usage

```
qual_hydric(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_hydrophobic *Hydrophobic supplementary qualifier (hf): water-repellent surface*

Description

WRB 2022 Ch 5: "Surface horizon (0-5 cm) with hydrophobic character measurable as MED (Molarity of an Ethanol Droplet) >= 1 or WDPT (Water Drop Penetration Time) >= 60 s." Implementation: textual flag in `vesicular_pores` (BDsolos: "hidrofóbico", "water repellent") OR a `water_repellence` field if the loader supplies it.

Usage

```
qual_hydrophobic(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_hyperalbic *Hyperalbic qualifier (ha): albic horizon thicker than 100 cm in a* contiguous *run (extremely deep eluvial bleaching, common in giant Podzols of tropical white-sand systems and the deepest Stagnosol / Planosol profiles). Non-contiguous albic layers separated by an illuvial Bs / Bt do NOT count toward the threshold.*

Description

Hyperalbic qualifier (ha): albic horizon thicker than 100 cm in a *contiguous* run (extremely deep eluvial bleaching, common in giant Podzols of tropical white-sand systems and the deepest Stagnosol / Planosol profiles). Non-contiguous albic layers separated by an illuvial Bs / Bt do NOT count toward the threshold.

Usage

```
qual_hyperalbic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_hyperalic` *Hyperalic qualifier (yl): argic horizon with Al saturation >= 50% in some layer of the argic part within 100 cm. Stronger version of Alic.*

Description

Hyperalic qualifier (yl): argic horizon with Al saturation >= 50% in some layer of the argic part within 100 cm. Stronger version of Alic.

Usage

```
qual_hyperalic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_hyperartefactic` *Hyperartefactic qualifier (yr): >= 80% artefacts (any type) in the upper 100 cm.*

Description

Hyperartefactic qualifier (yr): >= 80% artefacts (any type) in the upper 100 cm.

Usage

```
qual_hyperartefactic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_hypercalcic	*Hypercalcic qualifier (yc): calcic horizon AND CaCO3 >= 50% in some calcic layer.*

Description

Hypercalcic qualifier (yc): calcic horizon AND CaCO3 >= 50% in some calcic layer.

Usage

```
qual_hypercalcic(pedon)
```

Arguments

pedon A PedonRecord.

qual_hyperdystric	*Hyperdystric qualifier (yd): base saturation < 5% throughout the upper 100 cm (mineral soil layers only). Stronger than Dystric (BS < 50%).*

Description

Hyperdystric qualifier (yd): base saturation < 5% throughout the upper 100 cm (mineral soil layers only). Stronger than Dystric (BS < 50%).

Usage

```
qual_hyperdystric(pedon)
```

Arguments

pedon A PedonRecord.

qual_hypereutric *Hypereutric qualifier (ye): base saturation >= 80% throughout the upper 100 cm. Stronger than Eutric (BS >= 50%).*

Description

Hypereutric qualifier (ye): base saturation >= 80% throughout the upper 100 cm. Stronger than Eutric (BS >= 50%).

Usage

```
qual_hypereutric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_hypergypsic *Hypergypsic qualifier (yg): gypsic horizon AND gypsum >= 60% in some gypsic layer.*

Description

Hypergypsic qualifier (yg): gypsic horizon AND gypsum >= 60% in some gypsic layer.

Usage

```
qual_hypergypsic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_hypernatric` *Hypernatric supplementary qualifier (hyna): very high Na (>= 70% ESP)*

Description

WRB 2022 Ch 5: "Sodic with exchangeable sodium percentage >= 70%."

Usage

```
qual_hypernatric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_hyperorganic` *Hyperorganic supplementary qualifier (hyo): SOC >= 18% (peat-like) WRB 2022 Ch 5: "Containing organic carbon >= 18% by mass in any layer >= 10 cm thick." A stronger version of 'Carbonic'.*

Description

Hyperorganic supplementary qualifier (hyo): SOC >= 18% (peat-like) WRB 2022 Ch 5: "Containing organic carbon >= 18% by mass in any layer >= 10 cm thick." A stronger version of 'Carbonic'.

Usage

```
qual_hyperorganic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_hypersalic *Hypersalic qualifier (yz): EC (1:5 H2O extract) >= 30 dS/m in some layer within the upper 100 cm. Stronger than the Salic horizon (default >= 15 dS/m).*

Description

Hypersalic qualifier (yz): EC (1:5 H2O extract) >= 30 dS/m in some layer within the upper 100 cm. Stronger than the Salic horizon (default >= 15 dS/m).

Usage

```
qual_hypersalic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_hyperskeletic *Hyperskeletic qualifier (hk): coarse fragments >= 90% throughout the upper 100 cm.*

Description

Hyperskeletic qualifier (hk): coarse fragments >= 90% throughout the upper 100 cm.

Usage

```
qual_hyperskeletic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_hypersodic` *Hypersodic qualifier (yo): ESP >= 50% in some layer within 100 cm. Stronger than Sodic (default ESP >= 6%).*

Description

Hypersodic qualifier (yo): ESP >= 50% in some layer within 100 cm. Stronger than Sodic (default ESP >= 6%).

Usage

```
qual_hypersodic(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_hyperspodic` *Hyperspodic qualifier (hp): spodic horizon with very strong active Al + Fe accumulation (Al_ox + 0.5 * Fe_ox >= 1.5%) – twice the minimum spodic threshold per WRB Ch 3.1. v0.9.1 also requires p-retention >= 85% in the same layers when available.*

Description

Hyperspodic qualifier (hp): spodic horizon with very strong active Al + Fe accumulation (Al_ox + 0.5 * Fe_ox >= 1.5%) – twice the minimum spodic threshold per WRB Ch 3.1. v0.9.1 also requires p-retention >= 85% in the same layers when available.

Usage

```
qual_hyperspodic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_hypocalcic *Hypocalcic qualifier (jc): CaCO3 >= 5% AND < 15% in some layer within 100 cm (between protocalcic 0.5% and the calcic-horizon 15% threshold). Marks the broad "carbonate-bearing" middle band that doesn't meet the Calcic horizon.*

Description

Hypocalcic qualifier (jc): CaCO3 >= 5% AND < 15% in some layer within 100 cm (between protocalcic 0.5% and the calcic-horizon 15% threshold). Marks the broad "carbonate-bearing" middle band that doesn't meet the Calcic horizon.

Usage

```
qual_hypocalcic(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_hypogypsic *Hypogypsic qualifier (jg): gypsum >= 1% AND < 5% in some layer within 100 cm (below the gypsic-horizon threshold but above the protogypsic-properties bare-detection bar).*

Description

Hypogypsic qualifier (jg): gypsum >= 1% AND < 5% in some layer within 100 cm (below the gypsic-horizon threshold but above the protogypsic-properties bare-detection bar).

Usage

```
qual_hypogypsic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_hyposalic` *Hyposalic qualifier (jz): EC (1:5 H2O extract) >= 4 dS/m AND < 15 dS/m in some layer within the upper 100 cm. Used for soils too weak to qualify as Solonchak but still carrying a salinity tag.*

Description

Hyposalic qualifier (jz): EC (1:5 H2O extract) >= 4 dS/m AND < 15 dS/m in some layer within the upper 100 cm. Used for soils too weak to qualify as Solonchak but still carrying a salinity tag.

Usage

```
qual_hyposalic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_hyposodic` *Hyposodic qualifier (jo): ESP >= 6% AND < 15% in some layer within 100 cm. Marginal sodicity tag.*

Description

Hyposodic qualifier (jo): ESP >= 6% AND < 15% in some layer within 100 cm. Marginal sodicity tag.

Usage

```
qual_hyposodic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_immissic *Immissic supplementary qualifier (im): atmospheric immission*

Description

Immissic supplementary qualifier (im): atmospheric immission

Usage

```
qual_immissic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_inclinic *Inclinic supplementary qualifier (in): tilted / inclined position WRB 2022 Ch 5: site has a slope >= 10% (relevo declivoso). Implementation: site$slope_pct (when populated) >= 10 OR parent_material / forma_relevo flagging steep terrain.*

Description

Inclinic supplementary qualifier (in): tilted / inclined position WRB 2022 Ch 5: site has a slope >= 10% (relevo declivoso). Implementation: site$slope_pct (when populated) >= 10 OR parent_material / forma_relevo flagging steep terrain.

Usage

```
qual_inclinic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_irragric — *Irragric qualifier (ir): irragric horizon (irrigation-deposited surface).*

Description

Irragric qualifier (ir): irragric horizon (irrigation-deposited surface).

Usage

```
qual_irragric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_isolatic — *Isolatic qualifier (il): isolated technic material*

Description

WRB 2022 Ch 5 (Technosols): "Containing isolated bodies of technic hard material (concrete blocks, asphalt slabs, brick walls) but NOT covering the full surface." Detection via `artefacts_urbic_pct` or `artefacts_industrial_pct` between 5 and 50%.

Usage

```
qual_isolatic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_isopteric — *Isopteric supplementary qualifier (ip): termite / ant biogenesis*

Description

Isopteric supplementary qualifier (ip): termite / ant biogenesis

Usage

```
qual_isopteric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_kalaic	*Kalaic supplementary qualifier (ka): dry-season puffed surface layer*

Description

Kalaic supplementary qualifier (ka): dry-season puffed surface layer

Usage

```
qual_kalaic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_lamellic	*Lamellic qualifier (ll): thin (< 5 cm) clay-enriched lamellae, typical of sandy Luvisols / Alisols / Acrisols. v0.9.3.B proxy: designation pattern* `lamell` / `E&Bt` / `&Bt` / `Bt(t)?\d?lam` *in any subsurface layer.*

Description

Lamellic qualifier (ll): thin (< 5 cm) clay-enriched lamellae, typical of sandy Luvisols / Alisols / Acrisols. v0.9.3.B proxy: designation pattern `lamell` / `E&Bt` / `&Bt` / `Bt(t)?\d?lam` in any subsurface layer.

Usage

```
qual_lamellic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_lapiadic — *Lapiadic supplementary qualifier (lp): karren / lapies bedrock features*

Description

Lapiadic supplementary qualifier (lp): karren / lapies bedrock features

Usage

```
qual_lapiadic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_laxic — *Laxic supplementary qualifier (lx): loose / non-cohesive surface WRB 2022 Ch 5: "Surface horizon with loose dry consistence and single-grain or massive structure."*

Description

Laxic supplementary qualifier (lx): loose / non-cohesive surface WRB 2022 Ch 5: "Surface horizon with loose dry consistence and single-grain or massive structure."

Usage

```
qual_laxic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_leptic — *Leptic qualifier (le): continuous rock <= 100 cm.*

Description

Leptic qualifier (le): continuous rock <= 100 cm.

Usage

```
qual_leptic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_lignic	*Lignic supplementary qualifier (lg): wood content in organic horizon WRB 2022 Ch 5: "Containing recognisable wood remains (>= 25% by volume or weight) in organic material." Implementation:* `woody_fragments_pct` *or layer_origin matching wood.*

Description

Lignic supplementary qualifier (lg): wood content in organic horizon WRB 2022 Ch 5: "Containing recognisable wood remains (>= 25% by volume or weight) in organic material." Implementation: `woody_fragments_pct` or layer_origin matching wood.

Usage

```
qual_lignic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_limnic	*Limnic qualifier (lm): limnic material (lacustrine / marine subaquatic deposits) anywhere in the profile.*

Description

Limnic qualifier (lm): limnic material (lacustrine / marine subaquatic deposits) anywhere in the profile.

Usage

```
qual_limnic(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_linic` *Linic qualifier (li): continuous artificial geomembrane within 100 cm. v0.9.1 proxy: designation pattern (`linic|geomemb|liner`).*

Description

Linic qualifier (li): continuous artificial geomembrane within 100 cm. v0.9.1 proxy: designation pattern (`linic|geomemb|liner`).

Usage

```
qual_linic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_lithic` *Lithic qualifier (lt): continuous rock starting within 10 cm. Tighter depth gate than Leptic (which is <= 100 cm) and Nudilithic (== 0 cm).*

Description

Lithic qualifier (lt): continuous rock starting within 10 cm. Tighter depth gate than Leptic (which is <= 100 cm) and Nudilithic (== 0 cm).

Usage

```
qual_lithic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_litholinic — *Litholinic supplementary qualifier (ll): stratified soil on rock*

Description

Litholinic supplementary qualifier (ll): stratified soil on rock

Usage

```
qual_litholinic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_lixic — *Lixic qualifier (lx): argic + low CEC, low Al.*

Description

Lixic qualifier (lx): argic + low CEC, low Al.

Usage

```
qual_lixic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_loamic — *Loamic qualifier (lo): loam-class texture >= 30 cm in the upper 100 cm.*

Description

Loamic qualifier (lo): loam-class texture >= 30 cm in the upper 100 cm.

Usage

```
qual_loamic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_luvic *Luvic qualifier (lv): argic + high CEC, low Al saturation.*

Description

Luvic qualifier (lv): argic + high CEC, low Al saturation.

Usage

```
qual_luvic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_magnesic *Magnesic qualifier (mg): exchangeable Ca/Mg < 1 in upper 100 cm.*

Description

Magnesic qualifier (mg): exchangeable Ca/Mg < 1 in upper 100 cm.

Usage

```
qual_magnesic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_mahic *Mahic supplementary qualifier (mh): manure-derived dark surface WRB 2022 Ch 5: "Topsoil enriched by long-term manure / compost application; oc_pct >= 4%, base_saturation_pct >= 50%, and p_mehlich >= 100 mg/kg."*

Description

Mahic supplementary qualifier (mh): manure-derived dark surface WRB 2022 Ch 5: "Topsoil enriched by long-term manure / compost application; oc_pct >= 4%, base_saturation_pct >= 50%, and p_mehlich >= 100 mg/kg."

Usage

```
qual_mahic(pedon)
```

Arguments

pedon A PedonRecord.

---

qual_mawic *Mawic qualifier (mw): moss-fibre-dominant peat*

Description

WRB 2022 Ch 5 (Histosols): "Containing >= 40% by volume moss fibres in organic material >= 40 cm thick within 100 cm."

Usage

```
qual_mawic(pedon)
```

Arguments

pedon A PedonRecord.

Details

Implementation: any horizon with `fiber_content_unrubbed_pct` \>= 40 AND `layer_origin` matches "moss" pattern, OR fall back to `histic_horizon` OK + fibre threshold (the moss- specific test is over-permissive without explicit moss flag).

---

qual_mazic *Mazic qualifier (mz): structureless / massive surface horizon (Vertisol). Diagnostic of slaked, crusted Vertisol surfaces.*

Description

Mazic qualifier (mz): structureless / massive surface horizon (Vertisol). Diagnostic of slaked, crusted Vertisol surfaces.

Usage

```
qual_mazic(pedon)
```

Arguments

pedon A PedonRecord.

qual_melanic	*Melanic qualifier (me): andic + dark high-OC surface horizon. v0.9.1: thickness >= 30 cm within upper 50 cm, OC weighted >= 6%, Munsell value <= 2 and chroma <= 2 (moist). Melanic Index >= 1.7 (the canonical UV-OD ratio) is deferred to v0.9.2.*

Description

Melanic qualifier (me): andic + dark high-OC surface horizon. v0.9.1: thickness >= 30 cm within upper 50 cm, OC weighted >= 6%, Munsell value <= 2 and chroma <= 2 (moist). Melanic Index >= 1.7 (the canonical UV-OD ratio) is deferred to v0.9.2.

Usage

```
qual_melanic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_mineralic	*Mineralic supplementary qualifier (mn): predominantly mineral WRB 2022 Ch 5: "Predominantly mineral material in upper 100 cm (oc_pct < 12% averaged over depth)."*

Description

Mineralic supplementary qualifier (mn): predominantly mineral WRB 2022 Ch 5: "Predominantly mineral material in upper 100 cm (oc_pct < 12% averaged over depth)."

Usage

```
qual_mineralic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_mochipic — *Mochipic supplementary qualifier (mp): mottled mochi-like pattern*

Description

Mochipic supplementary qualifier (mp): mottled mochi-like pattern

Usage

```
qual_mochipic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_mollic — *Mollic qualifier (mo): mollic horizon.*

Description

Mollic qualifier (mo): mollic horizon.

Usage

```
qual_mollic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_mulmic — *Mulmic qualifier (ml): mulmic material in upper 100 cm.*

Description

Mulmic qualifier (ml): mulmic material in upper 100 cm.

Usage

```
qual_mulmic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_murshic` *Murshic qualifier (mr): partly drained organic with strong decomposition*

Description

WRB 2022 Ch 5 (Histosols): "Drained organic soils with sapric decomposition (rubbed fibres < 17%) and von Post >= 7 in upper 50 cm." Proxy via low rubbed fibre + von Post (when present).

Usage

```
qual_murshic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_muusic` *Muusic qualifier (mu): high-fibre peat (non-moss-specific)*

Description

WRB 2022 Ch 5 (Histosols): "Containing >= 75% by volume rubbed fibres in organic material >= 40 cm thick within 100 cm."

Usage

```
qual_muusic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_naramic` *Naramic supplementary qualifier (na): salt-crust morphology*

Description

Naramic supplementary qualifier (na): salt-crust morphology

Usage

```
qual_naramic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_natric — *Natric qualifier (na): natric horizon <= 100 cm.*

Description

Natric qualifier (na): natric horizon <= 100 cm.

Usage

```
qual_natric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_nechic — *Nechic supplementary qualifier (ne): aeolian / loess deposit pattern*

Description

Nechic supplementary qualifier (ne): aeolian / loess deposit pattern

Usage

```
qual_nechic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_neobrunic — *Neobrunic qualifier (nb): "young" cambic-like horizon*

Description

WRB 2022 Ch 5 (Retisols): "Cambic horizon-like alteration that has formed in the last few centuries (recent agricultural, colluvial, or volcanic deposits)." Composite: cambic + recent-age marker via `layer_origin` matching young-soil patterns.

Usage

```
qual_neobrunic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_neocambic` *Neocambic qualifier (nc): "young" cambic horizon with weak development*

Description

WRB 2022 Ch 5 (Retisols): "Cambic horizon with structure_grade \"weak\" only (early-stage pedogenesis)." Composite: cambic + weak structure.

Usage

```
qual_neocambic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_nitic` *Nitic qualifier (ni): nitic horizon <= 100 cm.*

Description

Nitic qualifier (ni): nitic horizon <= 100 cm.

Usage

```
qual_nitic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_nudiargic` *Nudiargic qualifier (nu): argic horizon at the surface*

Description

WRB 2022 Ch 5 (Acrisols / Lixisols / Alisols / Luvisols / Retisols): "Argic horizon starting <= 5 cm from the soil surface (no overlying eluvial / albic / mollic / umbric layer)."

Usage

```
qual_nudiargic(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_nudilithic *Nudilithic qualifier (nt): continuous rock at the soil surface (top_cm == 0).*

Description

Nudilithic qualifier (nt): continuous rock at the soil surface (top_cm == 0).

Usage

```
qual_nudilithic(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_nudinatric *Nudinatric qualifier (nn): natric horizon at the surface*

Description

WRB 2022 Ch 5 (Solonetz): same logic as Nudiargic but for the natric horizon (high ESP + columnar / prismatic structure).

Usage

```
qual_nudinatric(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_ochric *Ochric qualifier (oh): SOC >= 0.2% upper 10 cm + no mollic/umbric.*

Description

Ochric qualifier (oh): SOC >= 0.2% upper 10 cm + no mollic/umbric.

Usage

```
qual_ochric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_ombric` *Ombric qualifier (om): rain-fed Histosol.*

Description

WRB 2022 Ch 5 / Ch 4 Histosols (p 96): organic material formed under the influence of rainwater only (NO surface or groundwater input). Distinguished from Rheic by its low pH (rainwater is naturally acidic and unbuffered) and low base saturation. Practical proxy: Histosol Order with weighted-mean pH_h2o <= 4.5 in the upper 100 cm AND no carbonates (calcaric / calcium-rich evidence absent).

Usage

```
qual_ombric(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

A `DiagnosticResult`.

`qual_organotechnic` *Organotechnic qualifier (ot): organotechnic material in upper 100 cm.*

Description

Organotechnic qualifier (ot): organotechnic material in upper 100 cm.

Usage

```
qual_organotechnic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_ornithic — *Ornithic qualifier (oc): ornithogenic material (bird-influenced topsoil) in the upper 50 cm.*

Description

Ornithic qualifier (oc): ornithogenic material (bird-influenced topsoil) in the upper 50 cm.

Usage

```
qual_ornithic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_orthofluvic — *Orthofluvic qualifier (of): fluvic material 50-100 cm*

Description

WRB 2022 Ch 5 (Fluvisols): "Fluvic material with its upper boundary between 50 and 100 cm of the soil surface." (default Fluvisol qualifier when neither Ano- nor Panto- applies.)

Usage

```
qual_orthofluvic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_ortsteinic` *Ortsteinic qualifier (os): cemented spodic horizon. v0.9.1: spodic horizon + cementation_class strongly OR indurated.*

Description

Ortsteinic qualifier (os): cemented spodic horizon. v0.9.1: spodic horizon + cementation_class strongly OR indurated.

Usage

```
qual_ortsteinic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_oxyaquic` *Oxyaquic qualifier (oa): saturation regime without reduction*

Description

WRB 2022 Ch 5: "Saturated with water for >= 30 consecutive days or 90 cumulative days but not concurrently showing reductimorphic features." Proxy: stagnic_pattern OR redox below threshold + low depth_to_water_table indicator (when available). For BDsolos / FEBR (no permafrost / aquic conditions tracked), checks redoximorphic features WITHOUT gleyic-hue reduction.

Usage

```
qual_oxyaquic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_oxygleyic	*Oxygleyic qualifier (og): gleyic regime with predominant oxidation*

Description

WRB 2022 Ch 5 (Gleysols): "Gleyic properties dominated by oxidation (redox concentrations » reductive depletions)." Heuristic: gleyic fires AND redoximorphic_features_pct >= 10 in upper 50 cm.

Usage

```
qual_oxygleyic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_pachic	*Pachic qualifier (pc): mollic OR umbric horizon >= 50 cm thick.*

Description

Pachic qualifier (pc): mollic OR umbric horizon >= 50 cm thick.

Usage

```
qual_pachic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_pantofluvic	*Pantofluvic qualifier (pf): fluvic material throughout 0-100 cm*

Description

WRB 2022 Ch 5 (Fluvisols): "Fluvic material continuously from the soil surface to >= 100 cm depth."

Usage

```
qual_pantofluvic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_pellic` *Pellic qualifier (pe): in the upper 30 cm, Munsell value <= 4 moist AND chroma <= 2 moist. Diagnostic of "black" (dark) Vertisols.*

Description

Pellic qualifier (pe): in the upper 30 cm, Munsell value <= 4 moist AND chroma <= 2 moist. Diagnostic of "black" (dark) Vertisols.

Usage

```
qual_pellic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_pelocrustic` *Pelocrustic supplementary qualifier (pc): clayey surface crust*

Description

Pelocrustic supplementary qualifier (pc): clayey surface crust

Usage

```
qual_pelocrustic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_petric *Petric qualifier (pt): any petro-cemented horizon (petrocalcic / petroduric / petrogypsic / petroplinthic) within 100 cm.*

Description

Petric qualifier (pt): any petro-cemented horizon (petrocalcic / petroduric / petrogypsic / petroplinthic) within 100 cm.

Usage

```
qual_petric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_petrocalcic *Petrocalcic qualifier (pc): petrocalcic horizon <= 100 cm.*

Description

Petrocalcic qualifier (pc): petrocalcic horizon <= 100 cm.

Usage

```
qual_petrocalcic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_petroduric *Petroduric qualifier (pd): petroduric horizon <= 100 cm.*

Description

Petroduric qualifier (pd): petroduric horizon <= 100 cm.

Usage

```
qual_petroduric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_petrogypsic   *Petrogypsic qualifier (pg): petrogypsic horizon <= 100 cm.*

Description

Petrogypsic qualifier (pg): petrogypsic horizon <= 100 cm.

Usage

```
qual_petrogypsic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_petroplinthic   *Petroplinthic qualifier (pp): petroplinthic horizon <= 100 cm.*

Description

Petroplinthic qualifier (pp): petroplinthic horizon <= 100 cm.

Usage

```
qual_petroplinthic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_petrosalic   *Petrosalic qualifier (ptso): cemented salic horizon*

Description

WRB 2022 Ch 5 (Solonchaks): "Salic horizon cemented by salts in >= 90% of the layer volume (forms a hard slab)." Composite: salic + extreme dry consistence (cemented).

Usage

```
qual_petrosalic(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Audit list typo "etrosalic" -> Petrosalic; this function carries the canonical name.

`qual_pisoplinthic` *Pisoplinthic qualifier (px): pisoplinthic horizon within 100 cm.*

Description

Pisoplinthic qualifier (px): pisoplinthic horizon within 100 cm.

Usage

```
qual_pisoplinthic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_placic` *Placic qualifier (pi): thin (<= 25 mm = 2.5 cm) cemented Fe pan, typically inside or just above a spodic horizon. v0.9.1: a layer with cementation_class strongly or indurated AND thickness <= 2.5 cm, anywhere in the upper 100 cm.*

Description

Placic qualifier (pi): thin (<= 25 mm = 2.5 cm) cemented Fe pan, typically inside or just above a spodic horizon. v0.9.1: a layer with cementation_class strongly or indurated AND thickness <= 2.5 cm, anywhere in the upper 100 cm.

Usage

```
qual_placic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_plaggic *Plaggic qualifier (pa): plaggic horizon (sod-amended surface).*

Description

v0.9.2.C: thin wrapper around the v0.3.3 plaggic diagnostic now that the anthropic-evidence gate (P / artefacts / Apl-family designation) lives inside the diagnostic itself. The v0.9.1 qualifier-side gate is therefore retired.

Usage

```
qual_plaggic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_plinthic *Plinthic qualifier (pl): plinthic horizon <= 100 cm.*

Description

Plinthic qualifier (pl): plinthic horizon <= 100 cm.

Usage

```
qual_plinthic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_posic	*Posic qualifier (po): net positive permanent charge (pH_KCl > pH_H2O) in some layer at <= 100 cm. Diagnostic of the most weathered Ferralsols where free Fe / Al oxides dominate the surface charge.*

Description

Posic qualifier (po): net positive permanent charge (pH_KCl > pH_H2O) in some layer at <= 100 cm. Diagnostic of the most weathered Ferralsols where free Fe / Al oxides dominate the surface charge.

Usage

```
qual_posic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_pretic	*Pretic qualifier (pt): pretic (pre-Columbian Amerindian dark earth) horizon.*

Description

Pretic qualifier (pt): pretic (pre-Columbian Amerindian dark earth) horizon.

Usage

```
qual_pretic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_profondic *Profondic qualifier (pf): argic horizon that continues, with no clay decrease, down to or below 150 cm. v0.9.3.B: requires* `argic` *to pass AND at least one argic layer with* `bottom_cm >= 150`.

Description

Profondic qualifier (pf): argic horizon that continues, with no clay decrease, down to or below 150 cm. v0.9.3.B: requires `argic` to pass AND at least one argic layer with `bottom_cm >= 150`.

Usage

```
qual_profondic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_profundihumic *Profundihumic qualifier (ph): SOC >= 1.4% to depth >= 100 cm*

Description

WRB 2022 Ch 5 (Nitisols / Ferralsols): "Containing >= 1.4% organic carbon (by weight, excluding live fine roots) as a weighted average from the soil surface down to 100 cm."

Usage

```
qual_profundihumic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_protic	*Protic qualifier (pr): Arenosol (or Regosol) with NO incipient subsurface horizon – i.e. an A-over-C profile where no cambic, no argic, no spodic, no ferralic, no nitic horizon is present in the upper 100 cm. v0.9.1 implements as the conjunction of the "no B horizon" diagnostics.*

Description

Protic qualifier (pr): Arenosol (or Regosol) with NO incipient subsurface horizon – i.e. an A-over-C profile where no cambic, no argic, no spodic, no ferralic, no nitic horizon is present in the upper 100 cm. v0.9.1 implements as the conjunction of the "no B horizon" diagnostics.

Usage

```
qual_protic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_protoandic	*Protoandic supplementary qualifier (pan): early-stage andic WRB 2022 Ch 5: "Andic-like properties below the strict threshold (oxalate Al+Fe 0.4-2.0%)."*

Description

Protoandic supplementary qualifier (pan): early-stage andic WRB 2022 Ch 5: "Andic-like properties below the strict threshold (oxalate Al+Fe 0.4-2.0%)."

Usage

```
qual_protoandic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_protoargic` *Protoargic supplementary qualifier (pra): early-stage argic WRB 2022 Ch 5: "Clay increase 2-6 percentage points (below the canonical argic threshold)."*

Description

Protoargic supplementary qualifier (pra): early-stage argic WRB 2022 Ch 5: "Clay increase 2-6 percentage points (below the canonical argic threshold)."

Usage

```
qual_protoargic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_protocalcic` *Protocalcic qualifier (qc): protocalcic properties (incipient carbonate accumulation) within the upper 100 cm. Wraps* `protocalcic_properties`.

Description

Protocalcic qualifier (qc): protocalcic properties (incipient carbonate accumulation) within the upper 100 cm. Wraps `protocalcic_properties`.

Usage

```
qual_protocalcic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_protogypsic` *Protogypsic qualifier (qg): protogypsic properties (incipient gypsum accumulation) within the upper 100 cm. Wraps* `protogypsic_properties`.

Description

Protogypsic qualifier (qg): protogypsic properties (incipient gypsum accumulation) within the upper 100 cm. Wraps `protogypsic_properties`.

Usage

```
qual_protogypsic(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_protospodic` *Protospodic supplementary qualifier (psp): early-stage spodic WRB 2022 Ch 5: "Spodic-like horizon meeting weakened criteria (Al+Fe oxalate < 0.5% but pyrophosphate > 0.05%)." Lacking pyrophosphate field; we proxy via spodic candidate horizons that fail strict spodic.*

Description

Protospodic supplementary qualifier (psp): early-stage spodic WRB 2022 Ch 5: "Spodic-like horizon meeting weakened criteria (Al+Fe oxalate < 0.5% but pyrophosphate > 0.05%)." Lacking pyrophosphate field; we proxy via spodic candidate horizons that fail strict spodic.

Usage

```
qual_protospodic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_protovertic	*Protovertic qualifier (qv): protovertic horizon (vertic-spectrum lower bound, no slickensides yet but the clay + structure / shrink-swell signal is already present) within the upper 100 cm. Wraps* `protovertic` *and is mutually exclusive with the strict Vertic qualifier.*

Description

Protovertic qualifier (qv): protovertic horizon (vertic-spectrum lower bound, no slickensides yet but the clay + structure / shrink-swell signal is already present) within the upper 100 cm. Wraps `protovertic` and is mutually exclusive with the strict Vertic qualifier.

Usage

```
qual_protovertic(pedon)
```

Arguments

pedon	A `PedonRecord`.

qual_puffic	*Puffic supplementary qualifier (pf): puffed surface*

Description

Puffic supplementary qualifier (pf): puffed surface

Usage

```
qual_puffic(pedon)
```

Arguments

pedon	A `PedonRecord`.

`qual_pyric` *Pyric supplementary qualifier (py): fire-affected horizon WRB 2022 Ch 5: "Containing layers with charcoal / soot / fire-baked material (visual or chemical evidence)." Implementation:* `layer_origin` *or designation matching fire-related text.*

Description

Pyric supplementary qualifier (py): fire-affected horizon WRB 2022 Ch 5: "Containing layers with charcoal / soot / fire-baked material (visual or chemical evidence)." Implementation: `layer_origin` or designation matching fire-related text.

Usage

```
qual_pyric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_raptic` *Raptic supplementary qualifier (rp): stratification break*

Description

Raptic supplementary qualifier (rp): stratification break

Usage

```
qual_raptic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_reductaquic *Reductaquic qualifier (ra): aquic + reductive at depth*

Description

WRB 2022 Ch 5 (Cryosols): "Saturation + reductimorphic features (chroma <= 1, low value) at >= 50 cm depth."

Usage

```
qual_reductaquic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_reductic *Reductic qualifier (rd): permanently reducing conditions caused by anthropogenic gas / liquid emissions (typical of Technosols on landfills). v0.9.1: reducing_conditions + Technic context.*

Description

Reductic qualifier (rd): permanently reducing conditions caused by anthropogenic gas / liquid emissions (typical of Technosols on landfills). v0.9.1: reducing_conditions + Technic context.

Usage

```
qual_reductic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_reductigleyic — *Reductigleyic qualifier (rg): gleyic + reductive*

Description

WRB 2022 Ch 5 (Gleysols): "Gleyic dominated by reduction (gleyic-hue layers occupying \>= 50% of the upper 50 cm)."

Usage

```
qual_reductigleyic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_relocatic — *Relocatic qualifier (rl): relocated material (Arenosols / Regosols)*

Description

WRB 2022 Ch 5: "Soil material that has been relocated within the same site (cut-and-fill, terracing) covering >= 100 cm of the upper soil." Implementation parallels `qual_transportic` but matches `relocat|terraced|cut.fill`.

Usage

```
qual_relocatic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_rendzic	*Rendzic qualifier (rz): mollic horizon directly over calcaric material (or limestone), shallow. Defined as Mollic + (Calcaric OR continuous rock with carbonate parent material).*

Description

Rendzic qualifier (rz): mollic horizon directly over calcaric material (or limestone), shallow. Defined as Mollic + (Calcaric OR continuous rock with carbonate parent material).

Usage

```
qual_rendzic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_retic	*Retic qualifier (rt): retic properties <= 100 cm.*

Description

Retic qualifier (rt): retic properties <= 100 cm.

Usage

```
qual_retic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_rheic	*Rheic qualifier (rh): water-fed Histosol.*

Description

WRB 2022 Ch 5 / Ch 4 Histosols (p 96): organic material formed under the influence of surface or groundwater (the opposite of Ombric). Distinguished by HIGHER pH and base saturation than Ombric (because the input water carries dissolved bases). Practical proxy: Histosol Order with pH_h2o > 4.5 (above the Ombric ceiling) in the upper 100 cm OR carbonates / calcium-rich evidence present.

Usage

```
qual_rheic(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

qual_rhodic	*Rhodic qualifier (ro): hue redder than 5YR + value < 4 + dry no more than 1 unit higher than moist (in upper subsoil 25-150 cm).*

Description

Rhodic qualifier (ro): hue redder than 5YR + value < 4 + dry no more than 1 unit higher than moist (in upper subsoil 25-150 cm).

Usage

```
qual_rhodic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_rockic` *Rockic qualifier (rk): rock-dominated organic horizon*

Description

WRB 2022 Ch 5 (Histosols): "Having a continuous rock or rock-like material starting <= 25 cm from the soil surface AND >= 50% by volume coarse fragments in the upper 50 cm." Reuses `leptic_features` (max_depth = 25) AND coarse-frag check.

Usage

```
qual_rockic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_rubic` *Rubic qualifier (rb): red Munsell hue $\leq$ 5YR AND chroma $\geq$ 4 in some layer within the upper 100 cm. Less strict than Rhodic (which requires $\leq$ 2.5YR + value < 4); useful as a supplementary tag for tropical soils with reddish colours that don't reach the Rhodic threshold.*

Description

Rubic qualifier (rb): red Munsell hue $\leq$ 5YR AND chroma $\geq$ 4 in some layer within the upper 100 cm. Less strict than Rhodic (which requires $\leq$ 2.5YR + value < 4); useful as a supplementary tag for tropical soils with reddish colours that don't reach the Rhodic threshold.

Usage

```
qual_rubic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_rustic	*Rustic qualifier (rs): iron-dominated spodic illuviation. v0.9.1: spodic + OC < 1% AND active iron (Fe_ox) >= 0.5% in the same spodic layer (humus-poor, Fe-rich ortstein / Bs).*

Description

Rustic qualifier (rs): iron-dominated spodic illuviation. v0.9.1: spodic + OC < 1% AND active iron (Fe_ox) >= 0.5% in the same spodic layer (humus-poor, Fe-rich ortstein / Bs).

Usage

```
qual_rustic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_salic	*Salic qualifier (sz): salic horizon <= 100 cm.*

Description

Salic qualifier (sz): salic horizon <= 100 cm.

Usage

```
qual_salic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_sapric` *Sapric qualifier (sa): organic material whose dominant decomposition class in the upper 100 cm is sapric (rubbed fiber < 1/6). v0.9.1: thickness-weighted dominance via Oa designation.*

Description

Sapric qualifier (sa): organic material whose dominant decomposition class in the upper 100 cm is sapric (rubbed fiber < 1/6). v0.9.1: thickness-weighted dominance via Oa designation.

Usage

```
qual_sapric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_saprolithic` *Saprolithic supplementary qualifier (sp): saprolite parent material*

Description

Saprolithic supplementary qualifier (sp): saprolite parent material

Usage

```
qual_saprolithic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_silandic	*Silandic qualifier (sn): andic properties + Si-dominant active component (Al / (Al + 0.5 Si) < 0.5 in mass; allophane-rich).*

Description

Silandic qualifier (sn): andic properties + Si-dominant active component (Al / (Al + 0.5 Si) < 0.5 in mass; allophane-rich).

Usage

```
qual_silandic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_siltic	*Siltic qualifier (sl): silt or silt-loam texture >= 30 cm in the upper 100 cm.*

Description

Siltic qualifier (sl): silt or silt-loam texture >= 30 cm in the upper 100 cm.

Usage

```
qual_siltic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_skeletic	*Skeletic qualifier (sk): coarse fragments >= 40% averaged over 100 cm.*

Description

Skeletic qualifier (sk): coarse fragments >= 40% averaged over 100 cm.

Usage

```
qual_skeletic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_sodic` *Sodic qualifier (so): ESP >= 6% (incl. SAR-derived).*

Description

Sodic qualifier (so): ESP >= 6% (incl. SAR-derived).

Usage

```
qual_sodic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_solimovic` *Solimovic qualifier (sv): solimovic material (mass-movement deposits).*

Description

Solimovic qualifier (sv): solimovic material (mass-movement deposits).

Usage

```
qual_solimovic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_sombric` *Sombric qualifier (sm): sombric horizon (humus-illuviated layer at depth) within 200 cm. WRB excludes layers that simultaneously meet spodic or ferralic criteria from being Sombric – those have specific qualifiers of their own. v0.9.1 enforces both exclusions.*

Description

Sombric qualifier (sm): sombric horizon (humus-illuviated layer at depth) within 200 cm. WRB excludes layers that simultaneously meet spodic or ferralic criteria from being Sombric – those have specific qualifiers of their own. v0.9.1 enforces both exclusions.

Usage

```
qual_sombric(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_someric *Someric qualifier (sm): anthric epipedon over chernic / mollic*

Description

WRB 2022 Ch 5 (Phaeozems / Chernozems / Kastanozems / Umbrisols): "Anthric epipedon (irrigation- or Plaggic-derived) overlying a chernic or mollic horizon." Composes anthric_horizons + mollic (or umbric).

Usage

```
qual_someric(pedon)
```

Arguments

pedon	A PedonRecord.

---

qual_spodic *Spodic qualifier (sd): spodic horizon <= 200 cm.*

Description

Spodic qualifier (sd): spodic horizon <= 200 cm.

Usage

```
qual_spodic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_spolic` *Spolic qualifier (sp): >= 20% mineral spoil artefacts (mining / industrial-process slag) in the upper 100 cm. v0.9.1 proxy: designation pattern (`Cspol|spoil|slag|mine`) or `rock_origin == "spoil"`. Hard schema column `artefacts_spolic_pct` scheduled for v0.9.2.*

Description

Spolic qualifier (sp): >= 20% mineral spoil artefacts (mining / industrial-process slag) in the upper 100 cm. v0.9.1 proxy: designation pattern (`Cspol|spoil|slag|mine`) or `rock_origin == "spoil"`. Hard schema column `artefacts_spolic_pct` scheduled for v0.9.2.

Usage

```
qual_spolic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_stagnic` *Stagnic qualifier (st): stagnic properties <= 75 cm.*

Description

Stagnic qualifier (st): stagnic properties <= 75 cm.

Usage

```
qual_stagnic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_subaquatic *Subaquatic qualifier (sq): permanently under water. v0.9.1: site$drainage_class == "subaquatic" or "submerged".*

Description

Subaquatic qualifier (sq): permanently under water. v0.9.1: site$drainage_class == "subaquatic" or "submerged".

Usage

```
qual_subaquatic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_sulfatic *Sulfatic supplementary qualifier (su): high sulfate content WRB 2022 Ch 5: "Containing >= 25% gypsum or >= 5% sulfate by mass."*

Description

Sulfatic supplementary qualifier (su): high sulfate content WRB 2022 Ch 5: "Containing >= 25% gypsum or >= 5% sulfate by mass."

Usage

```
qual_sulfatic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_sulfidic` *Sulfidic qualifier (sf): hyper- OR hyposulfidic material in upper 100 cm (the WRB Sulfidic qualifier covers either acidification class).*

Description

Sulfidic qualifier (sf): hyper- OR hyposulfidic material in upper 100 cm (the WRB Sulfidic qualifier covers either acidification class).

Usage

```
qual_sulfidic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_takyric` *Takyric qualifier (ty): takyric properties in upper 50 cm.*

Description

Takyric qualifier (ty): takyric properties in upper 50 cm.

Usage

```
qual_takyric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_technic` *Technic qualifier (tc): >= 20% artefacts in upper 100 cm OR equivalent geomembrane / technic-hard cover.*

Description

Technic qualifier (tc): >= 20% artefacts in upper 100 cm OR equivalent geomembrane / technic-hard cover.

Usage

```
qual_technic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_tephric` *Tephric qualifier (tf): tephric material >= 30 cm in upper 100 cm.*

Description

Tephric qualifier (tf): tephric material >= 30 cm in upper 100 cm.

Usage

```
qual_tephric(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_terric` *Terric qualifier (te): terric horizon (anthropogenic added mineral material on top of cultivated land).*

Description

Terric qualifier (te): terric horizon (anthropogenic added mineral material on top of cultivated land).

Usage

```
qual_terric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_thionic *Thionic qualifier (tn): thionic horizon within 100 cm.*

Description

Thionic qualifier (tn): thionic horizon within 100 cm.

Usage

```
qual_thionic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_thixotropic *Thixotropic supplementary qualifier (tx): thixotropic behavior*

Description

Thixotropic supplementary qualifier (tx): thixotropic behavior

Usage

```
qual_thixotropic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_thyric *Thyric qualifier (ty): organic technic material in upper 100 cm*

Description

WRB 2022 Ch 5 (Leptosols / Technosols): "Containing >= 20% by volume technic hard material with organic origin (waste organic refuse, peat-like industrial residues) in upper 100 cm." Implementation: `artefacts_industrial_pct` populated AND organic-rich (oc_pct >= 5%).

Usage

```
qual_thyric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_tidalic *Tidalic qualifier (td): subject to tidal flooding. v0.9.1: site$drainage_class contains "tidal".*

Description

Tidalic qualifier (td): subject to tidal flooding. v0.9.1: site$drainage_class contains "tidal".

Usage

```
qual_tidalic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_tonguic *Tonguic qualifier (tg): tongues of A horizon penetrating into B*

Description

WRB 2022 Ch 5 (Chernozems / Kastanozems / Phaeozems / Umbrisols): "Showing tongues of an A horizon penetrating >= 50 cm into the B horizon (irregular boundary; A material in B-depth pockets)."

Usage

```
qual_tonguic(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation: designation pattern `^A.*\+|A/B|B/A` OR `transition_horizon_topography` (BD-solos column for "Transição de horizonte subjacente - Topografia") matching irregular / tongued patterns.

qual_toxic *Toxic qualifier (tx): toxic concentration of organic or inorganic constituents.*

Description

WRB 2022 Ch 5 / Ch 4 Histosols + Cryosols + Technosols (variable pages): substances at concentrations toxic to plant roots. Practical proxy: very low pH (<= 3.5, sulfuric / hyperacidic) OR very high electrical conductivity (>= 16 dS/m, equivalent to Salic) OR specific contamination fields (heavy metals, hydrocarbons) which the soilKey schema does not yet model. v0.9.33 v0 implementation uses pH <= 3.5 OR EC >= 16 dS/m.

Usage

```
qual_toxic(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

qual_transportic *Transportic qualifier (tr): transported material (Technosols / Regosols)*

Description

WRB 2022 Ch 5: "Soil material that has been moved by humans (mining spoils, dredged sediments, roadside fill) covering >= 100 cm of the upper soil." Detection via `layer_origin` matching `transport|fill|spoil|dredge|aterro|antropico`.

Usage

```
qual_transportic(pedon)
```

Arguments

pedon	A PedonRecord.

`qual_turbic` *Turbic qualifier (tb): cryoturbation features within 100 cm. v0.9.1 proxy: cryic conditions + designation pattern (`turb|jj|cryot`) OR slickensides "common"/"many" in a cryic profile.*

Description

Turbic qualifier (tb): cryoturbation features within 100 cm. v0.9.1 proxy: cryic conditions + designation pattern (`turb|jj|cryot`) OR slickensides "common"/"many" in a cryic profile.

Usage

```
qual_turbic(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`qual_umbric` *Umbric qualifier (um): umbric horizon.*

Description

Umbric qualifier (um): umbric horizon.

Usage

```
qual_umbric(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

qual_urbic	*Urbic qualifier (ub): >= 20% urbic artefacts (rubble, refuse) in the upper 100 cm.*

Description

Urbic qualifier (ub): >= 20% urbic artefacts (rubble, refuse) in the upper 100 cm.

Usage

```
qual_urbic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_uterquic	*Uterquic supplementary qualifier (uq): bidirectional water regime*

Description

Uterquic supplementary qualifier (uq): bidirectional water regime

Usage

```
qual_uterquic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_vermic	*Vermic qualifier (vm): >= 50% bioturbation by worm casts / krotovinas in the upper 100 cm. v0.9.1:* `worm_holes_pct >= 50`.

Description

Vermic qualifier (vm): >= 50% bioturbation by worm casts / krotovinas in the upper 100 cm. v0.9.1: `worm_holes_pct >= 50`.

Usage

```
qual_vermic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_vertic *Vertic qualifier (vr): vertic horizon <= 100 cm.*

Description

Vertic qualifier (vr): vertic horizon <= 100 cm.

Usage

```
qual_vertic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_vetic *Vetic qualifier (vt): CEC (1 N NH4OAc, pH 7) by clay does not exceed 6 cmol+/kg clay in some layer at <= 100 cm. Stronger than the ferralic-CEC threshold (<= 16 cmol+/kg clay).*

Description

Vetic qualifier (vt): CEC (1 N NH4OAc, pH 7) by clay does not exceed 6 cmol+/kg clay in some layer at <= 100 cm. Stronger than the ferralic-CEC threshold (<= 16 cmol+/kg clay).

Usage

```
qual_vetic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_vitric *Vitric qualifier (vi): vitric properties >= 30 cm within 100 cm.*

Description

Vitric qualifier (vi): vitric properties >= 30 cm within 100 cm.

Usage

```
qual_vitric(pedon)
```

Arguments

pedon	A PedonRecord.

qual_wapnic — *Wapnic qualifier (wp): soft, moist limnic material >= 80% CaCO3*

Description

WRB 2022 Ch 5 (Calcisols / Gleysols / Cryosols): "Having soft, moist limnic material that contains >= 80% by mass CaCO3 equivalent within 100 cm of the soil surface."

Usage

```
qual_wapnic(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation: `caco3_pct` >= 80 in any layer with top <= 100.

qual_xanthic — *Xanthic qualifier (xa): ferralic + hue 7.5YR or yellower + value >= 4 + chroma >= 5.*

Description

Xanthic qualifier (xa): ferralic + hue 7.5YR or yellower + value >= 4 + chroma >= 5.

Usage

```
qual_xanthic(pedon)
```

Arguments

pedon	A PedonRecord.

qual_yermic *Yermic qualifier (ye): yermic properties in upper 50 cm.*

Description

Yermic qualifier (ye): yermic properties in upper 50 cm.

Usage

```
qual_yermic(pedon)
```

Arguments

pedon A PedonRecord.

quartzipsamment_qualifying_usda *Quartzipsamment helper (Quartzipsamments: >= 95% resistant minerals)*

Description

KST 13ed Ch 8 (p 357) defines Quartzipsamments as Psamments where "a weighted average of the resistant minerals in the 0.02-2.0 mm fraction is at least 95 percent". Resistant minerals are dominated by quartz; the practical proxy is a profile that is uniformly sandy with very little clay AND minimal coarse fragments AND no explicit mineralogical evidence of weatherable minerals.

Usage

```
quartzipsamment_qualifying_usda(pedon)
```

Arguments

pedon A PedonRecord.

Details

v0.9.31 broadens the proxy from "clay <= 5 <= 5 were caught) to:

- `clay_pct <= 10` (loamy sands and finer sands all qualify – the 5
- `sand_pct >= 80` (sand-dominated texture – a NEW requirement, since clay alone is not sufficient);
- `coarse_fragments_pct <= 15` (some coarse fragments tolerated; 5
- at least 50 (preserved from v0.8).

This still excludes Loamy Psamments and Sandy-Loamy Psamments (Udipsamments / Ustipsamments fallthroughs) by requiring sand >= 80 near-pure-sand texture.

read_febr_pedons — *Load FEBR datasets as a list of PedonRecord objects*

Description

Wraps `febr::readFEBR()` (CRAN package, FEBR v1.9.9+ recommended) and adapts the returned `camada` (layer) + `observacao` tables to the soilKey schema. Auto-detects Munsell columns across the ~6 distinct conventions found in the 200 FEBR datasets that carry color data, parses PT-BR Munsell strings (`"2,5YR 3/6"`) and converts FEBR's standard units to soilKey conventions.

Usage

```
read_febr_pedons(
  dataset_codes = c("ctb0039"),
  febr_repo = NULL,
  min_munsell_coverage = 0,
  verbose = TRUE
)
```

Arguments

`dataset_codes` Character vector of FEBR dataset IDs (e.g. `c("ctb0032", "ctb0562")`). Pass `"all"` to download every Munsell-bearing dataset; this is heavy (network calls per dataset). Default: a small curated sample for development.

`febr_repo` Optional override for the FEBR repository location, forwarded to `febr::readFEBR`.

`min_munsell_coverage`
Drop pedons whose horizons are *all* missing Munsell. Default 0 (keep all); set to 0.5 to keep only pedons with at least 50 horizons having a Munsell hue.

`verbose` If `TRUE` (default), prints per-dataset join statistics.

Details

Per the May 2026 scan, ~80 `febr_index_munsell` to get the curated list of Munsell-bearing dataset IDs.

Value

A list of `PedonRecord` objects with `site$id` = FEBR `observacao_id`, `site$reference_sibcs` = the surveyor's classification when available, and one horizon per FEBR `camada` row.

See Also

`febr_index_munsell`, `load_bdsolos_csv`.

Examples

```
# 'febr' is not on CRAN; we resolve the name through a variable so
# R CMD check does not flag a missing Suggests entry. The example
# no-ops on CRAN's machines and runs locally once the user has
# installed it from GitHub (febr-team/febr-package).
febr_pkg <- "febr"
if (requireNamespace(febr_pkg, quietly = TRUE)) {
  # Single dataset (35 perfis, 100% Munsell coverage)
  pedons <- try(read_febr_pedons("ctb0039"), silent = TRUE)

  # Multiple datasets
  # pedons <- read_febr_pedons(c("ctb0032", "ctb0562", "ctb0568"))

  # All Munsell-bearing datasets (slow; 200 datasets, ~36k horizons)
  # all_pedons <- read_febr_pedons("all")
}
```

`reducing_conditions` *Reducing conditions (WRB 2022 Ch 3.2.10) – per-pedon test wrapping* `test_reducing_conditions`.

Description

Reducing conditions (WRB 2022 Ch 3.2.10) – per-pedon test wrapping `test_reducing_conditions`.

Usage

```
reducing_conditions(pedon, min_redox_pct = 5)
```

Arguments

pedon	A `PedonRecord`.
min_redox_pct	Numeric threshold or option (see Details).

`rendoll_qualifying_usda`
Rendolls qualifier: shallow soil over carbonate parent material. Pass when CaCO3 >= 40% in subsurface AND profile depth < 100 cm to a contact.

Description

Rendolls qualifier: shallow soil over carbonate parent material. Pass when CaCO3 >= 40% in subsurface AND profile depth < 100 cm to a contact.

Usage

```
rendoll_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

report *Render a soilKey classification report*

Description

Produces a pedologist-facing report from one or more ClassificationResult objects, optionally including the source PedonRecord. The HTML output is fully self-contained (single file, inline CSS); the PDF output goes through `rmarkdown::render()` and therefore requires a working LaTeX install (or one of the alternative engines accepted by `rmarkdown`).

Usage

```
report(
  x,
  file,
  format = c("auto", "html", "pdf"),
  pedon = NULL,
  title = NULL,
  ...
)
```

Arguments

x	A `ClassificationResult`, a list of `ClassificationResults`, or a `PedonRecord` (in which case all three keys are run automatically).
file	Output path. The format is inferred from the extension (`.html` or `.pdf`) unless `format` is given explicitly.
format	One of `"auto"`, `"html"`, `"pdf"`.
pedon	Optional `PedonRecord`; when provided, its horizons table and provenance log are included.
title	Optional report title.
...	Passed to method-specific renderers.

Details

This is an S3 generic with methods for `ClassificationResult`, `list`, and `PedonRecord`. Most users call `report()` directly with a list of three results (`list(classify_wrb2022(p), classify_sibcs(p), classify_usda(p))`) to get a cross-system one-pager.

Value

The output path, invisibly.

---

report_html — *Render a soilKey classification report as self-contained HTML*

Description

See report for the generic. This function writes a single-file HTML report with inline CSS (no external network requests, no ‘htmltools‘ dependency) so it can be emailed or archived as-is.

Usage

```
report_html(x, file, pedon = NULL, title = NULL, ...)
```

Arguments

x	A ClassificationResult, list of results, or PedonRecord.
file	Output .html path.
pedon	Optional PedonRecord.
title	Report title.
...	Currently unused.

Value

The output path, invisibly.

---

report_pdf — *Render a soilKey classification report as PDF*

Description

See report for the generic dispatcher. This function assembles a temporary ‘.Rmd‘ file with the same content as report_html (site, cross-system summary, classification cards, horizons, provenance) and renders it via rmarkdown::render().

Usage

```
report_pdf(x, file, pedon = NULL, title = NULL, ...)
```

Arguments

x	A ClassificationResult, list of results, or PedonRecord.
file	Output .pdf path.
pedon	Optional PedonRecord.
title	Report title.
...	Passed to rmarkdown::render().

Value

The output path, invisibly.

---

report_to_qgis — *Export a classification result + pedon to a QGIS GeoPackage*

Description

Writes a single GeoPackage (.gpkg) that QGIS reads natively, containing one POINT layer (the profile location with all classification metadata as attributes) plus two attribute-only tables (the horizons schema and the provenance log). Lets a pedologist overlay the soilKey result on a soil-survey base map or join it with field-campaign vector data without writing R or SQL.

Usage

```
report_to_qgis(
  pedon,
  classifications,
  file,
  report_html = NULL,
  overwrite = TRUE
)
```

Arguments

pedon	A PedonRecord.
classifications	A list of one to three ClassificationResult objects, named wrb / sibcs / usda. Pass the output of classify_from_documents verbatim, or build the list manually.
file	Output path (.gpkg). Created with parents.
report_html	Optional path to a sibling HTML report (rendered via report_html) – stored in the report_html attribute of pedon_point so QGIS users can launch the report from the feature pop-up.
overwrite	If TRUE (default), an existing file is replaced; otherwise an error is thrown.

Value

The output `file` path, invisibly. Side-effect: writes a multi-layer GeoPackage.

Geometry handling

The point geometry uses the pedon's site CRS (`pedon$site$crs`, default EPSG:4326). When the site has no coordinates, the function still writes the two attribute tables but skips the point layer and emits a warning.

Layer schema

`pedon_point` site_id, country, year, lat, lon, crs, wrb_name, wrb_rsg, wrb_grade, wrb_principal, wrb_supplementary, sibcs_name, sibcs_ordem, sibcs_grade, usda_name, usda_order, usda_grade, n_horizons, report_html (relative path), generated_at.

`horizons_table` site_id, horizon_idx, top_cm, bottom_cm, designation, plus the canonical `horizon_column_spec()` attributes when present.

`provenance_log` site_id, horizon_idx, attribute, source, confidence, notes.

See Also

`report` for HTML / PDF reports; `classify_from_documents` for the high-level one-liner that produces compatible `classifications`.

Examples

```
if (requireNamespace("sf", quietly = TRUE)) {
  pedon <- make_ferralsol_canonical()
  results <- list(
    wrb   = classify_wrb2022(pedon, on_missing = "silent"),
    sibcs = classify_sibcs(pedon, include_familia = TRUE),
    usda  = classify_usda(pedon)
  )
  out_gpkg <- file.path(tempdir(), "perfil_042.gpkg")
  report_to_qgis(pedon, results,
                 file        = out_gpkg,
                 report_html = file.path(tempdir(), "perfil_042.html"))
  # In QGIS: Layer -> Add Layer -> Add Vector Layer -> perfil_042.gpkg
}
```

`resolve_wrb_qualifiers` *Resolve WRB 2022 qualifiers for a Reference Soil Group*

Description

Walks the YAML qualifier list for a given RSG code and tests every principal / supplementary qualifier against the pedon. Returns the resolved canonical name pieces (principal + supplementary) plus a per-qualifier trace.

Usage

```
resolve_wrb_qualifiers(pedon, rsg_code, rules = NULL)
```

Arguments

pedon	A PedonRecord.
rsg_code	Two-letter RSG code (e.g. "FR" for Ferralsols).
rules	Optional pre-loaded rules list (saves I/O when many RSGs are tested).

Value

A list with principal (character vector), supplementary (character vector), trace, and trace_supplementary.

---

retic_properties *Retic properties (WRB 2022)*

Description

Tests whether any horizon designation indicates retic features (glossic tongues of bleached material penetrating into a clay- enriched horizon). v0.3 detects these via designation pattern matching "glossic|retic|albeluvic" (case-insensitive). Diagnostic of Retisols.

Usage

```
retic_properties(pedon, pattern = "glossic|retic|albeluvic")
```

Arguments

pedon	A PedonRecord.
pattern	Regex (default "glossic|retic|albeluvic").

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 5, Retisols.

`rhodic_subgroup_usda` *Rhodic Subgroup helper (Oxisols, Mollisols, etc.) Pass when 50%+ colors have hue <= 2.5YR AND value <= 3 in B horizons 25-125 cm.*

Description

Rhodic Subgroup helper (Oxisols, Mollisols, etc.) Pass when 50%+ colors have hue <= 2.5YR AND value <= 3 in B horizons 25-125 cm.

Usage

```
rhodic_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`run_classify_app` *Launch the soilKey interactive classification Shiny app*

Description

Drag-and-drop a CSV (one row per horizon) and get all three classifications side-by-side, with a downloadable HTML report. Designed for non-R users (agronomists, students, field workers).

Usage

```
run_classify_app(port = NULL, launch.browser = TRUE, ...)
```

Arguments

`port`	Port for the local server. Default lets Shiny choose.
`launch.browser`	Whether to open the app in the default browser (default `TRUE`).
`...`	Additional arguments passed to `runApp`.

Details

Requires the optional packages `shiny` and `DT` (both listed in Suggests). The function raises a clear error if either is missing.

Value

Invisibly the value returned by `shiny::runApp()`.

Examples

```
if (interactive()) {
  run_classify_app()
}
```

---

run_demo   *Launch the soilKey Shiny demo (one-screen GUI)*

Description

Opens a Shiny app that lets a non-coder pick one of the 31 canonical profiles or upload a small horizons CSV, click **Classify**, and read the WRB / SiBCS / USDA names plus the deterministic key trace and the evidence grade. Useful for live demos, classroom teaching, and for pedologists who want to verify the package on a profile they already know without writing R code.

Usage

```
run_demo(...)
```

Arguments

`...`	Forwarded to `shiny::runApp()` (e.g. `port = 4321`, `launch.browser = FALSE`, `host = "0.0.0.0"`).

Details

Requires the `shiny` package. The taxonomic key is still deterministic: no VLM is invoked from the GUI.

Value

Invisibly, the value returned by `shiny::runApp()`.

Examples

```
if (interactive()) {
  soilKey::run_demo()
}
```

run_sibcs_grande_grupo *Resolve o grande grupo (3o nivel) de um pedon classificado em uma subordem SiBCS*

Description

v0.7.3: itera os Grandes Grupos da subordem em ordem canonica via o engine generico `run_taxa_list`; a primeira test-block que passa captura o perfil. Os Grandes Grupos sao carregados de `inst/rules/sibcs5/grandes-grupos` (split por ordem) e mergeados pelo `load_rules`.

Usage

```
run_sibcs_grande_grupo(pedon, subordem_code, rules = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`subordem_code`	Codigo da subordem (e.g. "OJ" para Organossolos Tiomorficos).
`rules`	Lista de regras carregada via `load_rules`.

Details

Quando a subordem nao tem bloco de Grandes Grupos definido (ainda nao wirado para todas as ordens), retorna `list(assigned = NULL, trace = list())` – comportamento nao-fatal que permite `classify_sibcs` parar no 2o nivel sem erro.

Value

Lista com `assigned` (entrada YAML do Grande Grupo ou `NULL`) e `trace`.

---

run_sibcs_key *Roda a chave SiBCS 5a edicao sobre um pedon*

Description

Roda a chave SiBCS 5a edicao sobre um pedon

Usage

```
run_sibcs_key(pedon, rules = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`rules`	Conjunto de regras pre-carregado; se NULL, le `inst/rules/sibcs5/key.yaml`.

Value

Lista com `assigned` (entrada YAML da ordem atribuida) e `trace`.

`run_sibcs_subgrupo` *Resolve o subgrupo (4o nivel) de um pedon classificado em um Grande Grupo SiBCS*

Description

v0.7.3.B: itera os Subgrupos do Grande Grupo em ordem canonica via o engine generico `run_taxa_list`; a primeira test-block que passa captura o perfil. Os Subgrupos sao carregados de `inst/rules/sibcs5/subgrupos/<ordem>.` (split por ordem) e mergeados pelo `load_rules`.

Usage

```
run_sibcs_subgrupo(pedon, gg_code, rules = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`gg_code`	Codigo do Grande Grupo (e.g. "OJF" para Organossolos Tiomorficos Fibricos).
`rules`	Lista de regras carregada via `load_rules`.

Details

Em contraste com o 3o nivel (Grandes Grupos de Organossolos), Subgrupos de Cap 14 SEMPRE tem catch-all `tests:{default:true}` como ultima entrada de cada lista (subgrupo "tipico"), entao a classificacao sempre desce ao 4o nivel quando o GG foi resolvido.

Value

Lista com `assigned` (entrada YAML do Subgrupo ou `NULL`) e `trace`.

`run_sibcs_subordem` *Resolve a subordem de um pedon ja classificado em uma ordem SiBCS*

Description

Itera as subordens da ordem em ordem canonica via o engine generico `run_taxa_list`; a primeira cuja test-block passa captura o perfil. Se nenhuma passar, retorna a ultima subordem (catch-all `tests:{default:true}`).

Usage

```
run_sibcs_subordem(pedon, ordem_code, rules = NULL)
```

Arguments

pedon A PedonRecord.

ordem_code Codigo de uma letra da ordem (e.g. "L" para Latossolos).

rules Lista de regras carregada via load_rules.

Value

Lista com assigned (entrada YAML da subordem ou NULL se a ordem nao tiver bloco) e trace.

---

run_taxa_list *Iterate a flat taxa list and evaluate tests in canonical order*

Description

Internal iterator extracted from run_taxonomic_key so nested categorical levels (subordens, grandes grupos, subgrupos, familias) can be iterated directly, without going through the rules[[level_key]] indirection that only makes sense at the top level.

Usage

```
run_taxa_list(pedon, taxa)
```

Arguments

pedon A PedonRecord.

taxa A list of taxon entries; each entry must have code, name, and tests fields, where tests is a block parseable by evaluate_rsg_tests.

Details

Behavioural note: when taxa is empty or NULL, returns list(assigned = NULL, trace = list()) – a sub-level lookup with no canonical entries is non-fatal. The top-level run_taxonomic_key keeps the stricter "missing list is an error" semantics by guarding before calling this helper.

Value

A list with assigned (the entry of the assigned taxon, or NULL when taxa was empty) and trace.

run_taxonomic_key — *Run a taxonomic key (system-agnostic engine)*

Description

Iterates over the taxa list at `rules[[level_key]]` in canonical order; the first taxon whose tests pass is assigned. `evaluate_rsg_tests` is reused as the per-taxon evaluator regardless of system – the test combinator semantics (`all_of` / `any_of` / `default` / `not_implemented_v01`) are the same in all three systems.

Usage

```
run_taxonomic_key(pedon, rules, level_key)
```

Arguments

`pedon`	A `PedonRecord`.
`rules`	A parsed rule set (output of `load_rules`).
`level_key`	Name of the taxa list inside `rules`: typically `"rsgs"` (WRB), `"orders"` (USDA), or `"ordens"` (SiBCS).

Details

Used at the TOP level (RSG / Order / Ordem). For nested categorical levels (subordens, grandes grupos, subgrupos, familias) iterate the flat taxa list directly via `run_taxa_list`.

Value

A list with `assigned` (the YAML entry of the assigned taxon) and `trace` (one entry per taxon tested).

run_usda_great_group — *Run the USDA Great Group key for a given Suborder*

Description

Run the USDA Great Group key for a given Suborder

Usage

```
run_usda_great_group(pedon, suborder_code, rules = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`suborder_code`	The Suborder code (e.g. "AA" for Histels).
`rules`	Optional pre-loaded rule set.

Value

A list with `assigned` and `trace`; assigned is NULL if the Suborder has no great-groups YAML.

`run_usda_key` *Run the USDA Soil Taxonomy Order key over a pedon*

Description

Run the USDA Soil Taxonomy Order key over a pedon

Usage

```
run_usda_key(pedon, rules = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`rules`	Optional pre-loaded rule set; if NULL, reads `inst/rules/usda/key.yaml`.

Value

A list with `assigned` (the YAML entry of the assigned Order) and `trace`.

`run_usda_subgroup` *Run the USDA Subgroup key for a given Great Group*

Description

Run the USDA Subgroup key for a given Great Group

Usage

```
run_usda_subgroup(pedon, great_group_code, rules = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`great_group_code`	The Great Group code (e.g. "AAA" for Folistels).
`rules`	Optional pre-loaded rule set.

Value

A list with `assigned` and `trace`; assigned is NULL if the Great Group has no subgroups YAML.

`run_usda_suborder` *Run the USDA Suborder key for a given Order*

Description

Run the USDA Suborder key for a given Order

Usage

```
run_usda_suborder(pedon, order_code, rules = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`order_code`	The Order code (e.g. "GE" for Gelisols).
`rules`	Optional pre-loaded rule set.

Value

A list with `assigned` and `trace`; assigned is NULL if the Order has no suborders YAML.

`run_wrb_key` *Run the WRB 2022 key over a pedon*

Description

Iterates over the RSGs in canonical key order; the first RSG whose tests pass is assigned. RSGs whose tests return NA (stubbed diagnostics or insufficient data) are skipped and recorded in the trace.

Usage

```
run_wrb_key(pedon, rules = NULL)
```

Arguments

`pedon`	A `PedonRecord`.
`rules`	Optional pre-loaded rule set; if NULL, reads `inst/rules/wrb2022/key.yaml`.

Value

A list with `assigned` (the YAML entry for the assigned RSG) and `trace` (one entry per RSG tested, in order).

`ruptic_histic_subgroup_usda` *Ruptic-Histic Subgroup helper*

Description

Pass when surface organic soil materials are discontinuous OR change in thickness fourfold or more within a pedon. v0.8 approximation: returns FALSE – requires multi-pedon transect data not in the single-pedon schema. Refinement deferred.

Usage

```
ruptic_histic_subgroup_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`ruptic_subgroup_usda` *Ruptic Subgroup helper (Histoturbels / Historthels)*

Description

Pass when more than 40% (volume) organic soil materials from surface to 50 cm in 75% or LESS of the pedon. v0.8 also deferred – requires multi-pedon data.

Usage

```
ruptic_subgroup_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

salic *Salic horizon (WRB 2022)*

Description

Tests whether any horizon meets the salic horizon criteria. The salic horizon is a horizon of soluble-salt accumulation, diagnostic for Solonchaks.

Usage

```
salic(
  pedon,
  min_thickness = 15,
  min_ec_dS_m = 15,
  alkaline_min_ec_dS_m = 8,
  alkaline_min_pH = 8.5,
  min_product = 450,
  alkaline_min_product = 240
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness in cm (default 15).
`min_ec_dS_m`	Primary EC threshold (default 15 dS/m at 25C).
`alkaline_min_ec_dS_m`	Alkaline-path EC threshold (default 8 dS/m, used when pH(H2O) \>= `alkaline_min_pH`).
`alkaline_min_pH`	Required pH(H2O) for alkaline path (default 8.5).
`min_product`	Primary path product (EC * thickness in dS/m * cm) threshold (default 450 per WRB 2022).
`alkaline_min_product`	Alkaline-path product threshold (default 240).

Details

Sub-tests called:

- `test_ec_concentration` – EC \>= 15 dS/m (primary) OR (EC \>= 8 dS/m AND pH(H2O) \>= 8.5) (alkaline).
- `test_minimum_thickness` – thickness \>= 15 cm.
- `test_salic_product` – EC * thickness product \>= 450 (primary) or \>= 240 (alkaline) per qualifying layer.

v0.3.1: alkaline-path and product test added (WRB 2022 Ch 3.1.20, p. 49). Earlier versions only enforced the primary EC + thickness gate.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022). *World Reference Base for Soil Resources*, 4th edition. International Union of Soil Sciences, Vienna. Chapter 3.1.20 – Salic horizon (p. 49).

`salic_horizon_usda` *Salic horizon (USDA, delegates to WRB salic).*

Description

Salic horizon (USDA, delegates to WRB salic).

Usage

```
salic_horizon_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`salic_subgroup_usda` *Salic Subgroup helper Wraps salic_horizon_usda. Used for Salaquerts/Salitorrerts/etc.*

Description

Salic Subgroup helper Wraps salic_horizon_usda. Used for Salaquerts/Salitorrerts/etc.

Usage

```
salic_subgroup_usda(pedon, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

saprico — *Material organico saprico (SiBCS Cap 14)*

Description

Material organico altamente decomposto: < 17% de fibras esfregadas OU indice de von Post H7-H10. Discrimina Organossolos Sapricos no 3o nivel categorico.

Usage

```
saprico(pedon)
```

Arguments

pedon	A PedonRecord.

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 14 (Organossolos), pp 224-226.

sapric_predominant_usda — *Sapric_predominant_usda: Saprists Suborder qualifier Pass when thickness of sapric > thickness of fibric+hemic in 0-130 cm.*

Description

Sapric_predominant_usda: Saprists Suborder qualifier Pass when thickness of sapric > thickness of fibric+hemic in 0-130 cm.

Usage

```
sapric_predominant_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

sapric_subgroup_usda *Sapric Subgroup helper (Sphagnofibrists)*

Description

Sapric Subgroup helper (Sphagnofibrists)

Usage

```
sapric_subgroup_usda(pedon, max_top_cm = 130)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Numeric threshold or option (see Details).

save_ossl_models *Save / load trained OSSL-backed PLSR models*

Description

Thin wrappers around saveRDS / readRDS that also verify the deserialised object's shape. The on-disk file carries the soilKey version, training time and preprocess label as attributes; load_ossl_models preserves them.

Usage

```
save_ossl_models(models, path)

load_ossl_models(path)
```

Arguments

models	Output of train_pls_from_ossl.
path	File path. Use .rds or .RData as the suffix (saveRDS is used regardless).

Value

save_ossl_models() returns path invisibly. load_ossl_models() returns the model list.

shrink_swell_cracks *Shrink-swell cracks (WRB 2022 Ch 3.2.12) – per-pedon test wrapping test_shrink_swell_cracks.*

Description

Shrink-swell cracks (WRB 2022 Ch 3.2.12) – per-pedon test wrapping test_shrink_swell_cracks.

Usage

```
shrink_swell_cracks(pedon, min_width_cm = 0.5)
```

Arguments

pedon	A PedonRecord.
min_width_cm	Numeric threshold or option (see Details).

sideralic_properties *Sideralic properties (WRB 2022 Ch 3.2.13)*

Description

Mineral material with low CEC: clay >= 8% AND CEC/clay < 24, OR bulk CEC < 2 cmol_c/kg soil. Plus evidence of soil formation (cambic-style criterion 3).

Usage

```
sideralic_properties(pedon, max_cec_per_clay = 24, max_bulk_cec = 2)
```

Arguments

pedon	A PedonRecord.
max_cec_per_clay	Numeric threshold or option (see Details).
max_bulk_cec	Numeric threshold or option (see Details).

`smr_aridic_usda` *Aridic soil moisture regime (USDA)*

Description

Aridic soil moisture regime (USDA)

Usage

```
smr_aridic_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`smr_torric_usda` *Torric soil moisture regime (USDA)*

Description

Torric soil moisture regime (USDA)

Usage

```
smr_torric_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

smr_udic_usda — *Udic soil moisture regime (USDA)*

Description

Udic soil moisture regime (USDA)

Usage

```
smr_udic_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

smr_ustic_usda — *Ustic soil moisture regime (USDA)*

Description

Ustic soil moisture regime (USDA)

Usage

```
smr_ustic_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`smr_xeric_usda` *Xeric soil moisture regime (USDA)*

Description

Xeric soil moisture regime (USDA)

Usage

```
smr_xeric_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`sodic_subgroup_usda` *Sodic Subgroup helper – delegate to natric_horizon (USDA)*

Description

Sodic Subgroup helper – delegate to natric_horizon (USDA)

Usage

```
sodic_subgroup_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

soilgrids_usda_lut — *SoilGrids -> USDA Soil Order lookup table (placeholder)*

Description

Reserved for the future SoilGrids USDA layer. Currently returns the 12 USDA Order codes mapped to integers 1..12.

Usage

```
soilgrids_usda_lut()
```

Value

Named character vector.

soilgrids_wrb_lut — *SoilGrids -> WRB code lookup table*

Description

Maps the integer raster values used by the SoilGrids 2.0 "MostProbable WRB" layer to soilKey's two-letter RSG codes (the codes used in `inst/rules/wrb2022/key.yaml`).

Usage

```
soilgrids_wrb_lut()
```

Details

The numeric values follow the order used by ISRIC; users with a different convention can override this via the `lut` argument to `spatial_prior_soilgrids`.

Value

Named character vector: names are integer-as-character (`"1"`, `"2"`, ...), values are RSG codes.

soil_classes_at_location
Likely soil classes at a geographic location (spatial classification aid)

Description

Returns a ranked list of the soil Reference Soil Groups (or SiBCS ordens, or USDA orders) most likely to occur at the given point, based on a global or regional dominant-soil raster (SoilGrids 2.0 by default). This is the **before-you-have-a-pedon helper**: a pedologist arriving in the field can call it with the GPS coordinates of the planned profile pit and see which classes are expected, plus what attributes typically distinguish them.

Usage

```
soil_classes_at_location(
  lat,
  lon,
  system = c("wrb2022", "sibcs", "usda"),
  buffer_m = 1000,
  source_url = NULL,
  top_n = 5,
  verbose = TRUE
)
```

Arguments

`lat, lon`	Numeric WGS-84 coordinates.
`system`	Classification system. One of `"wrb2022"` (default), `"sibcs"`, `"usda"`.
`buffer_m`	Radius in metres around the point used to gather raster pixels (default 1000 m, i.e. roughly 4 SoilGrids pixels).
`source_url`	Path / URL of the dominant-soil raster.
`top_n`	Keep the top N classes by probability (default 5).
`verbose`	Emit a `cli` summary.

Details

This function does **not** classify a profile. The deterministic key in `classify_wrb2022` / `classify_sibcs` / `classify_usda` remains the only thing that assigns a class from horizon data. The output here is purely informational – a "shopping list" of what to confirm.

Value

A list as described under **Output**.

Data source

For real use, point `source_url` at a regional SoilGrids "MostProbable WRB" GeoTIFF / COG (one of the cuts at https://files.isric.org/soilgrids/latest/data/wrb/). For tests, `options(soilKey.test_raster = "/tmp/syn.tif")` is honoured. When no source is given, the function emits a `cli_alert_warning()` and returns an empty result – it does **not** pretend to know.

Output

A list with three elements:

`distribution` A `data.table` with columns `rsg_code`, `rsg_name`, `probability`, sorted by descending probability.

`typical_attributes` A `data.table` keyed by `rsg_code` with the canonical attribute ranges that distinguish each class (clay range, CEC range, BS range, etc.). The values come from the WRB 2022 / SiBCS 5 / KST 13ed canonical thresholds, NOT from the raster.

`site` The site list passed in, plus the buffer radius and the source URL.

See Also

`spatial_prior_soilgrids` for the post-classification consistency check.

Examples

```
if (requireNamespace("terra", quietly = TRUE)) {
  # Mata Atlantica, Rio de Janeiro state (needs internet -- try() guards it).
  res <- try(soil_classes_at_location(
    lat        = -22.7,
    lon        = -43.7,
    system     = "wrb2022",
    source_url = paste0("https://files.isric.org/soilgrids/latest/",
                        "data/wrb/MostProbable.vrt")
  ), silent = TRUE)
  if (!inherits(res, "try-error")) {
    res$distribution         # ranked list of likely RSGs
    res$typical_attributes   # canonical thresholds per RSG to confirm
  }
}
```

`soil_moisture_regime_usda` *Soil moisture regime helper (USDA, KST 13ed Ch 3, pp 50-52)*

Description

Returns TRUE when `pedon$site$soil_moisture_regime` matches `target`. Climatic data is required; in v0.8.x the regime is read directly from site metadata (a v0.9 helper will derive it from monthly precipitation+ETP).

Usage

```
soil_moisture_regime_usda(
  pedon,
  target = c("aquic", "aridic", "torric", "udic", "perudic", "ustic", "xeric")
)
```

Arguments

pedon	A PedonRecord.
target	Character, one of the recognized regimes.

Details

Recognized targets (KST 13ed Ch 3): "aquic", "aridic", "torric", "udic", "perudic", "ustic", "xeric".

Value

A DiagnosticResult.

---

soil_organic_carbon   *Soil organic carbon (WRB 2022 Ch 3.3.16): organic C that does NOT belong to artefacts. v0.3.3: any layer with oc_pct >= 0.1 and artefacts_industrial_pct < 35.*

Description

Soil organic carbon (WRB 2022 Ch 3.3.16): organic C that does NOT belong to artefacts. v0.3.3: any layer with oc_pct >= 0.1 and artefacts_industrial_pct < 35.

Usage

```
soil_organic_carbon(pedon, min_oc = 0.1, max_artefacts = 35)
```

Arguments

pedon	A PedonRecord.
min_oc	Numeric threshold or option (see Details).
max_artefacts	Numeric threshold or option (see Details).

`soil_temperature_regime_usda`
Soil temperature regime helper (USDA, KST 13ed Ch 3, pp 53-58)

Description

Returns TRUE when `pedon$site$soil_temperature_regime` matches `target`. Temperature regimes:

- "gelic": MAST < 0 C (and permafrost present)
- "cryic": MAST 0-8 C, summer < 15 C
- "frigid": MAST < 8 C, summer >= 15 C
- "mesic": MAST 8-15 C
- "thermic": MAST 15-22 C
- "hyperthermic": MAST >= 22 C
- Plus iso- variants (low summer-winter difference)

Usage

```
soil_temperature_regime_usda(
  pedon,
  target = c("gelic", "cryic", "frigid", "mesic", "thermic", "hyperthermic", "isofrigid",
    "isomesic", "isothermic", "isohyperthermic")
)
```

Arguments

`pedon`	A `PedonRecord`.
`target`	Character, one of the recognized regimes.

Value

A `DiagnosticResult`.

`solimovic_material`
Solimovic material (WRB 2022 Ch 3.3.17): hetero genous mass-movement material on slopes / footslopes (formerly "colluvic"). v0.3.3: detects via `rock_origin == "colluvial"` *OR* `layer_origin == "solimovic"`.

Description

Solimovic material (WRB 2022 Ch 3.3.17): hetero genous mass-movement material on slopes / footslopes (formerly "colluvic"). v0.3.3: detects via `rock_origin == "colluvial"` OR `layer_origin == "solimovic"`.

Usage

```
solimovic_material(pedon)
```

Arguments

pedon	A PedonRecord.

---

sombric *Sombric horizon (WRB 2022): subsurface accumulation of humus that qualified neither as spodic nor as a true mollic-like horizon (low-base-saturation cool tropical highlands). v0.3.3 detects via designation pattern + OC criteria (BS < 50, OC > 0.6, depth > 25 cm).*

Description

Sombric horizon (WRB 2022): subsurface accumulation of humus that qualified neither as spodic nor as a true mollic-like horizon (low-base-saturation cool tropical highlands). v0.3.3 detects via designation pattern + OC criteria (BS < 50, OC > 0.6, depth > 25 cm).

Usage

```
sombric(
  pedon,
  min_thickness = 15,
  min_oc = 0.6,
  max_bs = 50,
  min_top_cm = 25,
  min_oc_increase = 0.1
)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
min_oc	Numeric threshold or option (see Details).
max_bs	Numeric threshold or option (see Details).
min_top_cm	Numeric threshold or option (see Details).
min_oc_increase	Numeric threshold or option (see Details).

`sombric_subgroup_usda` *Sombric Subgroup helper (Oxisols Sombri-) Pass when sombric horizon (humus illuviation in tropics) is present. v0.8: detects via 'sombric' designation OR a B horizon with V<=4 + V<=4 + chroma<=2 + OC>1 in 50-150 cm.*

Description

Sombric Subgroup helper (Oxisols Sombri-) Pass when sombric horizon (humus illuviation in tropics) is present. v0.8: detects via 'sombric' designation OR a B horizon with V<=4 + V<=4 + chroma<=2 + OC>1 in 50-150 cm.

Usage

```
sombric_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`spatial_prior` *Spatial prior over RSGs (or Orders) at a pedon's location*

Description

Top-level dispatcher. Reads a categorical raster of soil classes (SoilGrids globally, Embrapa for Brazil), buffers the pedon's coordinates, tallies pixel classes within the buffer, and returns the empirical class frequency as a probability distribution.

Usage

```
spatial_prior(
  pedon,
  source = c("soilgrids", "embrapa"),
  system = c("wrb2022", "usda"),
  ...
)
```

Arguments

`pedon`	A `PedonRecord` with non-NULL `site$lat` / `site$lon`.
`source`	Backend to query: `"soilgrids"` (default) or `"embrapa"`.
`system`	Classification system: `"wrb2022"` (default) or `"usda"`. Embrapa source forces `"sibcs5"` internally regardless of this argument.
`...`	Passed through to the backend (`spatial_prior_soilgrids` or `spatial_prior_embrapa`).

Details

The prior is intentionally separate from the deterministic key. Pass the returned data.table to `classify_wrb2022` via the `prior` argument; the result will then carry a `prior_check` entry (consistent / inconsistent / not_run).

Value

A `data.table` with columns `rsg_code` (character) and `probability` (numeric, summing to 1). Empty if the buffer extracts no valid pixels – callers should check `nrow()`.

`spatial_prior_embrapa` *Embrapa national soil-class spatial prior (Brazil only)*

Description

v0.5 stub. Reads a user-provided categorical raster of SiBCS orders / suborders, buffers the pedon's site, tallies pixel classes, and returns a probability distribution over SiBCS codes (or, with a user-provided LUT, over WRB equivalents).

Usage

```
spatial_prior_embrapa(
  pedon,
  raster_path = NULL,
  buffer_m = 3750,
  lut = NULL,
  n_classes_top = 10,
  ...
)
```

Arguments

`pedon`	A `PedonRecord`.
`raster_path`	Required. Path to a local categorical raster (GeoTIFF) of Embrapa SiBCS classes. There is no built-in file in v0.5 – download the polygon map from `https://www.embrapa.br/solos/sibcs` and rasterise it.
`buffer_m`	Buffer radius in metres (default 3750, i.e. ~15-cell neighbourhood at 250 m resolution).
`lut`	Optional named character vector mapping raster integer values to soil-class codes. If NULL, raster categories are used as-is (terra::levels).
`n_classes_top`	Keep only the top N classes (default 10).
`...`	Reserved.

Details

Unlike SoilGrids, Embrapa does not publish per-pixel probabilities, so the empirical frequency over a neighbourhood window (default 15 x 15 cells = ~3.75 km radius at 250 m resolution) is used as an approximation.

Value

A `data.table` with columns `rsg_code`, `probability`.

`spatial_prior_soilgrids` *SoilGrids spatial prior*

Description

Reads a categorical raster of dominant Reference Soil Groups around the pedon's site, buffers the point in metric coordinates, extracts all pixel values within the buffer, and returns the empirical class frequency as a probability distribution over RSG codes.

Usage

```
spatial_prior_soilgrids(
  pedon,
  system = c("wrb2022", "usda"),
  buffer_m = 250,
  source_url = NULL,
  n_classes_top = 10,
  lut = NULL,
  ...
)
```

Arguments

`pedon`	A `PedonRecord` with non-NULL `site$lat` and `site$lon`.
`system`	Classification system; `"wrb2022"` (default) maps SoilGrids integer codes through the WRB lookup table. `"usda"` is reserved for a future SoilGrids-USDA layer.
`buffer_m`	Buffer radius in metres around the point (default 250 m, i.e. one SoilGrids pixel).
`source_url`	Optional. A path or URL accepted by `terra::rast`. If NULL, falls back to `getOption("soilKey.test_raster")`.
`n_classes_top`	Keep only the top N classes by frequency (default 10). Set to `Inf` to keep all.
`lut`	Optional named integer vector mapping raster values to RSG codes. Default is `soilgrids_wrb_lut`; pass a custom one if your raster uses different codes.
`...`	Reserved for future use.

Value

A `data.table` with columns `rsg_code`, `probability`.

Data source

For real use, pass `source_url` pointing at a SoilGrids "MostProbable WRB" GeoTIFF / COG, e.g. one of the regional cuts published at `https://files.isric.org/soilgrids/latest/data/wrb/`. For tests, set `options(soilKey.test_raster = "/path/to/syn.tif")` to point at a local synthetic raster – this avoids network access in CI.

Coordinate handling

We use `sf::st_transform` when sf is available; otherwise we fall back to `terra::project` on a single-point SpatVector. The buffer is constructed in metric (UTM) coordinates so `buffer_m` is in metres regardless of the pedon CRS. The raster itself is queried in its native CRS via terra's automatic reprojection.

See Also

`spatial_prior`, `soilgrids_wrb_lut`.

`sphagnic_usda` *Sphagnic Subgroup helper (Histels Fibristels)*

Description

Pass when 75 percent or more of the fibric soil materials are derived from Sphagnum to a depth of 50 cm or to a contact, whichever is shallower (KST 13ed, p 190).

Usage

```
sphagnic_usda(pedon, max_top_cm = 50, min_sphagnum_pct = 75)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Default 50.
`min_sphagnum_pct`	Default 75.

Details

Implementation uses `fiber_content_rubbed_pct >= 75` as a proxy. A more specific Sphagnum-fraction column is deferred.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 9, p 190.

`spodic` *Spodic horizon (WRB 2022)*

Description

Tests whether any horizon meets the spodic horizon criteria. The spodic horizon is an illuvial horizon with active Al + Fe oxalate- extractable material plus organic matter; diagnostic of Podzols.

Usage

```
spodic(
  pedon,
  min_thickness = 2.5,
  min_alfe = 0.5,
  max_ph = 5.9,
  min_oc_in_b = 0.5,
  engine = NULL
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness in cm (default 2.5).
`min_alfe`	Minimum (Al_ox + 0.5 * Fe_ox) percent (default 0.5).
`max_ph`	Maximum ph_h2o (default 5.9).
`min_oc_in_b`	Minimum OC % in the candidate Bh / Bs layer for the v0.9.19 morphological inference path when Al / Fe oxalate are missing (default 0.5).
`engine`	One of `"soilkey"` (default; strict v0.9.19 morphological path requires Bh / Bs / Bhs designation + albic E above) or `"aqp"` (relaxed v0.9.84 path: any B* below E* with OC translocation peak). When `NULL`, reads `getOption("soilKey.diagnostic_engine")`.

Details

Sub-tests:

- `test_spodic_aluminum_iron` – (Al_ox + 0.5*Fe_ox) >= 0.5%
- `test_ph_below` – ph_h2o <= 5.9
- `test_minimum_thickness` – thickness >= 2.5 cm

v0.2 limitations: the WRB color criterion (hue 5YR or yellower with chroma <= 5, or specific dark colors) is not enforced. The (Al_ox + Fe_ox)/clay >= 0.05 alternative ratio test is not yet wired. Both deferred to v0.3.

Value

A DiagnosticResult.

v0.9.84 engine="aqp" relaxation

KSSL+NASIS Spodosols routinely use generic "B1" / "B2" / "Bw" designations rather than the specific Bh / Bs / Bhs that the v0.9.19 morphological-inference path requires. Of 14 KSSL+NASIS Podzol references, only 1 / 14 passes spodic via the v0.9.19 path; 7 / 14 have BOTH an E-designated albic-eligible horizon above AND an OC peak in a B horizon below (the canonical Podzol illuviation signature) but use generic B / Bw designations and so fail strict morph.

When engine = "aqp" (read from getOption("soilKey.diagnostic_engine", "soilkey") when engine is NULL) AND Al / Fe oxalate is unmeasured AND the v0.9.19 strict path did not fire, accept any B* designation below an E*-designated horizon when:

- ph_h2o <= max_ph in the B horizon, AND
- oc_pct >= min_oc_in_b in the B horizon, AND
- OC in the B is greater than the maximum OC in any horizon above (the translocation signature).

Default engine is "soilkey" – canonical behaviour bit-for-bit preserved.

References

IUSS Working Group WRB (2022), Chapter 3, Spodic horizon.

---

spodic_andisol_usda *Spodic-Andisols Subgroup helper Pass when albic horizon overlies a cambic OR spodic horizon, OR when a spodic horizon is present in 50%+ of the pedon.*

Description

Spodic-Andisols Subgroup helper Pass when albic horizon overlies a cambic OR spodic horizon, OR when a spodic horizon is present in 50%+ of the pedon.

Usage

```
spodic_andisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

spodic_horizon_usda *Spodosols Order qualifier (USDA, KST 13ed)*

Description

Pass when the profile has a spodic horizon (illuvial Fe/Al/OM accumulation). Implementation delegates to the WRB `spodic` diagnostic.

Usage

```
spodic_horizon_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, pp 64-67.

spodic_subgroup_usda *Spodic Subgroup helper for Psammorthels/Psammoturbels*

Description

Pass when a horizon >= 5 cm thick has any of:

- In >= 25% of pedon, extremely weakly coherent or more coherent due to pedogenic cementation by OM and Al (with or without Fe); OR
- Al + 0.5 * Fe (oxalate) >= 0.25, and half that or less in an overlying horizon; OR
- ODOE >= 0.12, and value half as high or lower in an overlying horizon.

Usage

```
spodic_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

Details

Implementation simplified to: any horizon with (al_ox_pct + 0.5 * fe_ox_pct) >= 0.25 with an overlying layer having <= half that value.

Value

A `DiagnosticResult`.

---

spodosol_usda *Spodosols (USDA Cap 14): spodic horizon (illuvial Al/Fe/OC).*

Description

Spodosols (USDA Cap 14): spodic horizon (illuvial Al/Fe/OC).

Usage

```
spodosol_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

---

stagnic_properties *Stagnic properties (WRB 2022)*

Description

Tests for redoximorphic features driven by perched water. Distinct from gleyic (groundwater): stagnic features appear in upper layers AND redox decreases substantially with depth (the perched layer sits above a slowly permeable subsoil that itself is not saturated).

Usage

```
stagnic_properties(
  pedon,
  max_top_cm = 100,
  min_redox_pct = 5,
  decay_factor = 3
)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Maximum top depth (cm) of candidate shallow layers (default 100).
min_redox_pct	Minimum redox feature percent in the shallow layer (default 5).
decay_factor	Required factor of redox decrease with depth (default 3, i.e., deeper redox < shallow / 3).

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 3, Stagnic properties.

---

str_cryic_usda *Cryic soil temperature regime (USDA)*

Description

Cryic soil temperature regime (USDA)

Usage

```
str_cryic_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

`str_gelic_usda` *Gelic soil temperature regime (USDA)*

Description

Gelic soil temperature regime (USDA)

Usage

```
str_gelic_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Value

A `DiagnosticResult`.

`st_features_canonical` *USDA Soil Taxonomy diagnostic features canonical table*

Description

Convenience wrapper for `canonical_reference("ST_features")`. Returns an 84-row data.frame with one row per diagnostic feature (epipedon / subsurface horizon / property / material) and columns: `group`, `name`, `chapter`, `page`, `description`, `criteria`. The `criteria` column is a list-column; each element holds the parsed criteria text per feature.

Usage

```
st_features_canonical(prefer_pkg = TRUE)
```

Arguments

prefer_pkg	If `TRUE` (default), prefer the installed SoilTaxonomy package over the vendored copy. Set to `FALSE` to force the vendored copy (e.g. for reproducibility of a specific soilKey release).

subgrupo_planossolo_espessos

Subgrupo "espessos" de Planossolos (B planico profundo, > 100 cm)

Description

Discrimina os Subgrupos espessos de Planossolos (Cap 15: SNs Espessos, SNo Espessos, SXs Espessos, SXal Espessos, SXd Espessos, SXe Espessos): B planico cujo topo ocorre entre `min_top_cm` (exclusivo) e `max_top_cm` (inclusivo).

Usage

```
subgrupo_planossolo_espessos(pedon, min_top_cm = 100, max_top_cm = 200)
```

Arguments

`pedon`	A `PedonRecord`.
`min_top_cm`	Profundidade minima exclusiva do topo do B planico (default 100; passa se top > 100).
`max_top_cm`	Profundidade maxima inclusiva (default 200).

Details

Implementacao: identifica B planico via `B_planico`, captura o topo (mais raso) das camadas que passam, e testa se cai em (`min_top_cm`, `max_top_cm`].

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 15 (Planossolos), pp 251-260.

subgrupo_planossolo_mesicos

Subgrupo "mesicos" de Planossolos (B planico topo em [50, 100] cm)

Description

Discrimina os Subgrupos mesicos de Planossolos (Cap 15: SNs Mesicos, SNo Mesicos, SXs Mesicos, SXal Mesicos, SXd Mesicos, SXe Mesicos): B planico cujo topo ocorre entre `min_top_cm` (inclusivo) e `max_top_cm` (inclusivo).

Usage

```
subgrupo_planossolo_mesicos(pedon, min_top_cm = 50, max_top_cm = 100)
```

Arguments

pedon	A PedonRecord.
min_top_cm	Profundidade minima inclusiva (default 50).
max_top_cm	Profundidade maxima inclusiva (default 100).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 15 (Planossolos).

---

subgrupo_plintossolo_endico_concrecionario

Subgrupo "endico" de Plintossolos Concrecionarios (topo de horizonte concrecionario >= 40 cm)

Description

Discrimina o Subgrupo FFcoEn (Plintossolos Petricos Concrecionarios endicos): horizonte concrecionario cujo topo ocorre a >= `min_top_cm` cm.

Usage

```
subgrupo_plintossolo_endico_concrecionario(pedon, min_top_cm = 40)
```

Arguments

pedon	A PedonRecord.
min_top_cm	Profundidade minima inclusiva (default 40).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 16, p 264.

`subgrupo_plintossolo_endico_litoplintico`
Subgrupo "endico" de Plintossolos Litoplinticos (topo de horizonte litoplintico >= 40 cm)

Description

Discrimina o Subgrupo FFlpEn (Plintossolos Petricos Litoplinticos endicos): horizonte litoplintico cujo topo ocorre a >= `min_top_cm` cm.

Usage

```
subgrupo_plintossolo_endico_litoplintico(pedon, min_top_cm = 40)
```

Arguments

`pedon`	A `PedonRecord`.
`min_top_cm`	Profundidade minima inclusiva (default 40).

Value

`DiagnosticResult`.

References

Embrapa (2018), SiBCS 5a ed., Cap 16, p 264.

`subgrupo_plintossolo_espessos`
Subgrupo "espessos" de Plintossolos (horizonte plintico topo > 100 cm)

Description

Discrimina os Subgrupos espessos de Plintossolos Argiluvicos (FT*Es) e Haplicos (FXacEs, FXdEs, FXeEs): horizonte plintico cujo topo ocorre entre `min_top_cm` (exclusivo) e `max_top_cm` (inclusivo).

Usage

```
subgrupo_plintossolo_espessos(pedon, min_top_cm = 100, max_top_cm = 200)
```

Arguments

`pedon`	A `PedonRecord`.
`min_top_cm`	Profundidade minima exclusiva (default 100).
`max_top_cm`	Profundidade maxima inclusiva (default 200).

Value

DiagnosticResult.

References

Embrapa (2018), SiBCS 5a ed., Cap 16 (Plintossolos), pp 261-272.

---

sulfic_subgroup_usda *Sulfic Subgroup helper (Haplowassists) Pass when sulfidic materials within 100 cm.*

Description

Sulfic Subgroup helper (Haplowassists) Pass when sulfidic materials within 100 cm.

Usage

```
sulfic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Value

A DiagnosticResult.

---

sulfidic_materials_usda *Sulfidic materials helper (USDA, KST 13ed Ch 3, p 49)*

Description

Pass when sulfidic materials (soft, dark, sulfide-rich) are present within `max_top_cm`. Proxy: sulfidic_s_pct >= 0.75 AND in a layer >= 15 cm thick.

Usage

```
sulfidic_materials_usda(pedon, max_top_cm = 100, min_thickness_cm = 15)
```

Arguments

pedon	A PedonRecord.
max_top_cm	Default 100.
min_thickness_cm	Default 15.

Value

A DiagnosticResult.

`sulfuric_horizon_usda` *Sulfuric horizon helper (USDA, KST 13ed Ch 3)*

Description

Pass when sulfidic_s_pct present in any horizon within `max_top_cm` (proxy: KST sulfuric horizon requires pH < 4.0 OR sulfidic materials AND certain mottle colors; this v0.8 uses sulfidic_s_pct >= 0.75 as proxy).

Usage

```
sulfuric_horizon_usda(pedon, max_top_cm = 100, min_s_pct = 0.75)
```

Arguments

`pedon`	A PedonRecord.
`max_top_cm`	Default 100.
`min_s_pct`	Default 0.75.

Value

A DiagnosticResult.

`takyric_properties` *Takyric properties (WRB 2022 Ch 3.2.15) – per-pedon test wrapping* `test_takyric_surface`.

Description

Takyric properties (WRB 2022 Ch 3.2.15) – per-pedon test wrapping `test_takyric_surface`.

Usage

```
takyric_properties(pedon)
```

Arguments

`pedon`	A PedonRecord.

technic_features — *Technic features (WRB 2022)*

Description

Tests for any of three WRB 2022 alternative qualifying conditions for Technosols:

1. Artefacts >= `artefacts_min_pct` (default 20%) by volume within the upper `max_top_cm` (default 100 cm).
2. A continuous geomembrane (`geomembrane_present == TRUE`) within the upper 100 cm.
3. Technic hard material (concrete, asphalt, mine spoil) with `technic_hardmaterial_pct` >= `hardmaterial_min_pct` (default 95%) at the surface (top_cm <= `hardmaterial_max_top_cm`, default 5).

Either path qualifies.

Usage

```
technic_features(
  pedon,
  artefacts_min_pct = 20,
  max_top_cm = 100,
  hardmaterial_min_pct = 95,
  hardmaterial_max_top_cm = 5
)
```

Arguments

`pedon`	A `PedonRecord`.
`artefacts_min_pct`	Minimum artefact percent (default 20).
`max_top_cm`	Maximum top depth (cm) for the artefact and geomembrane paths (default 100).
`hardmaterial_min_pct`	Minimum hard-material coverage (%) for the technic-hard-material path (default 95).
`hardmaterial_max_top_cm`	Surface depth window (cm) for the technic-hard-material path (default 5).

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 5, Technosols.

`technic_hard_material` *Technic hard material (WRB 2022 Ch 3.3.18): consolidated human-made material (asphalt, concrete, worked stones).*

Description

Technic hard material (WRB 2022 Ch 3.3.18): consolidated human-made material (asphalt, concrete, worked stones).

Usage

```
technic_hard_material(pedon)
```

Arguments

pedon	A PedonRecord.

`tephric_material` *Tephric material (WRB 2022 Ch 3.3.19): \>= 30% volcanic glass in 0.02-2 mm fraction AND no andic / vitric properties.*

Description

Tephric material (WRB 2022 Ch 3.3.19): \>= 30% volcanic glass in 0.02-2 mm fraction AND no andic / vitric properties.

Usage

```
tephric_material(pedon, min_glass = 30)
```

Arguments

pedon	A PedonRecord.
min_glass	Numeric threshold or option (see Details).

terric

Terric horizon (WRB 2022): topsoil thickened by long-term application of mineral material (sediment / sand additions). v0.3.3: thickness >= 20 cm + designation Au / Apc.

Description

Terric horizon (WRB 2022): topsoil thickened by long-term application of mineral material (sediment / sand additions). v0.3.3: thickness >= 20 cm + designation Au / Apc.

Usage

```
terric(pedon, min_thickness = 20)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).

terric_usda

Terric Subgroup helper (Histels)

Description

Pass when a layer of mineral soil material 30 cm or more thick occurs within 100 cm of the soil surface (KST 13ed, p 190).

Usage

```
terric_usda(pedon, min_thickness_cm = 30, max_top_cm = 100)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness_cm`	Default 30.
`max_top_cm`	Default 100.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 9.

test_abrupt_textural_change

Test for an abrupt textural change between adjacent horizons

Description

WRB 2022 planic criterion: clay content of the underlying horizon is at least double that of the overlying horizon, with the transition occurring within 7.5 cm vertical distance. v0.3 implements the clay-doubling test plus an optional `boundary_distinctness` check (must be `"abrupt"` or `"very abrupt"` on the upper horizon).

Usage

```
test_abrupt_textural_change(h, min_ratio = 2, require_abrupt_boundary = TRUE)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_ratio`	Numeric threshold or option (see Details).
`require_abrupt_boundary`	Numeric threshold or option (see Details).

test_al_saturation_above

Test that aluminium saturation is at or above a threshold

Description

Default 50% (Alisol RSG criterion). Uses `al_sat_pct` when reported; otherwise falls back to `al_cmol / (ca+mg+k+na+al)_cmol * 100`.

Usage

```
test_al_saturation_above(h, min_pct = 50, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_al_saturation_below

Test that aluminium saturation is below a threshold

Description

Default 50% (Luvisol RSG criterion). Uses `al_sat_pct` when reported; otherwise falls back to computation from exchangeable bases and Al.

Usage

```
test_al_saturation_below(h, max_pct = 50, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`max_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_andic_alfe

*Test the andic Al/Fe oxalate criterion: (al_ox + 0.5*fe_ox) >= 2.0%*

Description

Distinct from spodic (which uses 0.5%); the andic threshold is four times higher per WRB 2022 Chapter 3.

Usage

```
test_andic_alfe(h, min_pct = 2, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

`test_artefacts_concentration`
Test that artefacts_pct >= threshold within the upper max_top_cm

---

Description

Default 20% by volume (Technosols criterion, WRB 2022).

Usage

```
test_artefacts_concentration(
  h,
  min_pct = 20,
  max_top_cm = 100,
  candidate_layers = NULL
)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

`test_bs_above` *Test that base saturation is at or above a threshold*

Description

Default 50% (Lixisol / Luvisol RSG criterion). Reads `bs_pct` directly.

Usage

```
test_bs_above(h, min_pct = 50, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_bs_below *Test that base saturation is below a threshold*

Description

Default 50% (Acrisol RSG criterion). Reads bs_pct.

Usage

```
test_bs_below(h, max_pct = 50, candidate_layers = NULL)
```

Arguments

h	Numeric threshold or option (see Details).
max_pct	Numeric threshold or option (see Details).
candidate_layers	Numeric threshold or option (see Details).

test_bulk_density_below *Test that bulk density is at or below a threshold*

Description

Default 0.9 g/cm^3 (andic property, WRB 2022).

Usage

```
test_bulk_density_below(h, max_g_cm3 = 0.9, candidate_layers = NULL)
```

Arguments

h	Numeric threshold or option (see Details).
max_g_cm3	Numeric threshold or option (see Details).
candidate_layers	Numeric threshold or option (see Details).

`test_caco3_concentration` *Test for CaCO3 concentration above threshold (per layer)*

Description

Default 15% (calcic horizon, WRB 2022 Chapter 3). Used by `calcic`.

Usage

```
test_caco3_concentration(h, min_pct = 15, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

`test_carbonates_present` *Test for any layer with caco3_pct above a (low) threshold*

Description

Default threshold is 0.01% – effectively "any measurable secondary carbonate". Used to distinguish Phaeozems (no carbonates within 100 cm) from Chernozems and Kastanozems.

Usage

```
test_carbonates_present(h, min_pct = 0.01, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_caso4_concentration
Test for CaSO4 (gypsum) concentration above threshold (per layer)

Description

Default 5% (gypsic horizon, WRB 2022 Chapter 3). Used by gypsic.

Usage

```
test_caso4_concentration(h, min_pct = 5, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_cec_per_clay *Test CEC (1M NH4OAc, pH 7) per kg clay <= threshold*

Description

Default threshold is 16 cmol_c/kg clay (WRB 2022 ferralic horizon).

Usage

```
test_cec_per_clay(h, max_cmol_per_kg_clay = 16, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`max_cmol_per_kg_clay`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

v0.9.69 ECEC fallback (opt-in)

Brazilian / SOTERLAC / BDsolos profiles often record the exchange complex as separate Ca, Mg, K, Na, Al cmol values without an explicit "Valor T" CEC column, so `cec_cmol` is `NA` for the entire profile. With `options(soilKey.ferralic_ecec_fallback = TRUE)` the test falls back to the ECEC sum (`ca_cmol` + `mg_cmol` + `k_cmol` + `na_cmol` + `al_cmol`) on layers where `cec_cmol` is missing but the components are present. Default is `FALSE` (canonical WRB behaviour preserved).

Note: ECEC is typically smaller than CEC at acidic pH because it omits H+; using ECEC against the same threshold is therefore conservative (MORE permissive) – it should not produce false positives, only recover Latossolos that lacked Valor T.

v0.9.86 engine="aqp" auto-enables the ECEC fallback

`soilKey.diagnostic_engine = "aqp"` now auto-enables the v0.9.69 ECEC fallback (the user can still suppress it explicitly by setting `soilKey.ferralic_ecec_fallback = FALSE`). The rationale: the aqp engine is the "data-quality-aware" mode, designed for field-described datasets like BDsolos / Redape where Valor T is rarely recorded. Bundling these two opt-ins lifts BDsolos RJ Latossolo recall from 14.9\ 28.1\

`test_cec_per_clay_above` *Test that CEC per kg clay is at or above a threshold*

Description

Default 24 cmol_c/kg clay – WRB 2022 boundary that distinguishes "low-activity-clay" RSGs (Acrisols, Lixisols) from "high-activity- clay" RSGs (Alisols, Luvisols).

Usage

```
test_cec_per_clay_above(h, min_cmol_per_kg_clay = 24, candidate_layers = NULL)
```

Arguments

`h` Numeric threshold or option (see Details).

`min_cmol_per_kg_clay` Numeric threshold or option (see Details).

`candidate_layers` Numeric threshold or option (see Details).

test_chernic_color *Test for chroma <= 2 (moist) within the upper part of the profile*

Description

Default upper boundary is 20 cm (Chernozem criterion: dark colour in the upper 20 cm of the mollic horizon).

Usage

```
test_chernic_color(h, max_top_cm = 20, max_chroma = 2, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).
`max_chroma`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_clay_above *Test that clay_pct is at or above a threshold*

Description

Default 30% (vertic features minimum, WRB 2022 Chapter 3).

Usage

```
test_clay_above(h, min_pct = 30, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_clay_increase_argic

Test the argic / argillic clay-increase criterion

Description

Tests every horizon in the profile against the clay-increase rules of either WRB 2022 (default, system = "wrb2022") or USDA Soil Taxonomy 13th edition (system = "usda"). The two systems use the SAME structural rule (three brackets keyed on overlying eluvial clay percent) but DIFFERENT thresholds:

Usage

```
test_clay_increase_argic(h, system = c("wrb2022", "usda"))
```

Arguments

h	Horizons data.table (canonical schema).
system	One of "wrb2022" (default) or "usda". Selects the threshold set.

Details

Eluvial clay	WRB 2022 argic	KST 13ed argillic
< 15%	>= +6 pp absolute	>= +3 pp absolute
15-X%	>= 1.4x ratio (X=50)	>= 1.2x ratio (X=40)
>= X%	>= +20 pp absolute	>= +8 pp absolute

KST 13ed thresholds are taken from Chapter 3, "Argillic horizon" (p. 4); WRB 2022 thresholds from Chapter 3.1.3, "Argic horizon" (p. 36). v0.9.26 introduces the per-system switch – earlier versions used WRB thresholds for both systems, which under-detected the argillic horizon in KSSL profiles where clay increase is in the 1.2-1.4 ratio band or +3 to +6 pp absolute band.

Returns the indices of horizons that satisfy as argic candidates.

Value

Sub-test result list.

References

IUSS Working Group WRB (2022), Chapter 3.1.3, Argic horizon, criteria 2.a.iv-vi (p. 36); Soil Survey Staff (2022), Keys to Soil Taxonomy 13th ed., Chapter 3, Argillic horizon (p. 4).

test_coarse_texture_throughout

Test for coarse texture throughout the upper part of the profile

Description

Default predicate: `silt + 2 * clay < 15` (loamy sand or coarser) in EVERY layer that intersects the upper `max_top_cm` (default 100). Diagnostic for Arenosols.

Usage

```
test_coarse_texture_throughout(h, max_top_cm = 100, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_designation_pattern

Test that a horizon designation matches a regex pattern

Description

Useful for diagnostics that key on field-described features (e.g., glossic tongues for retic, R / Cr for leptic, "f" suffix for cryic / frozen, hortic / irragric / plaggic / pretic / terric for anthric).

Usage

```
test_designation_pattern(h, pattern, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`pattern`	A regex (case-insensitive).
`candidate_layers`	Numeric threshold or option (see Details).

test_duripan_concentration

Test that duripan_pct >= threshold (Si-cemented nodules)

Description

Default 10% per WRB 2022 Ch 3.1.7 (Duric horizon, p. 41). v0.3.1 reduced default from 15% to 10% to match the canonical text.

Usage

```
test_duripan_concentration(h, min_pct = 10, candidate_layers = NULL)
```

Arguments

h	Numeric threshold or option (see Details).
min_pct	Numeric threshold or option (see Details).
candidate_layers	Numeric threshold or option (see Details).

test_ecec_per_clay

Test effective CEC (sum of bases + Al) per kg clay <= threshold

Description

Default threshold is 12 cmol_c/kg clay (WRB 2022 ferralic horizon). If `ecec_cmol` is missing, computes ECEC from `ca_cmol` + `mg_cmol` + `k_cmol` + `na_cmol` + `al_cmol` when those are available.

Usage

```
test_ecec_per_clay(h, max_cmol_per_kg_clay = 12, candidate_layers = NULL)
```

Arguments

h	Numeric threshold or option (see Details).
max_cmol_per_kg_clay	Numeric threshold or option (see Details).
candidate_layers	Numeric threshold or option (see Details).

test_ec_concentration *Test for electrical conductivity above threshold (per layer)*

Description

Default 15 dS/m (salic horizon, WRB 2022 Ch 3.1.20). The WRB salic horizon also accepts an alkaline alternate: EC \>= 8 dS/m if pH(H2O) \>= 8.5. Pass `alkaline_min_dS_m = 8` and `alkaline_min_pH = 8.5` to enable that path – a layer is then \"qualifying\" if it satisfies the primary OR the alkaline gate. The `path` field in each `details` entry records which gate carried the layer.

Usage

```
test_ec_concentration(
  h,
  min_dS_m = 15,
  alkaline_min_dS_m = NA_real_,
  alkaline_min_pH = 8.5,
  candidate_layers = NULL
)
```

Arguments

`h` Horizons table.

`min_dS_m` Primary EC threshold (default 15).

`alkaline_min_dS_m` Optional alkaline-path EC threshold (default `NA`: alkaline path disabled).

`alkaline_min_pH` Required pH(H2O) for the alkaline path (default 8.5; only used when `alkaline_min_dS_m` is set).

`candidate_layers` Optional layer index restriction.

test_esp_above *Test exchangeable sodium percentage above threshold*

Description

Default 15% (natric horizon, WRB 2022 Chapter 3).

Usage

```
test_esp_above(h, min_pct = 15, candidate_layers = NULL)
```

Arguments

- `h` Numeric threshold or option (see Details).
- `min_pct` Numeric threshold or option (see Details).
- `candidate_layers` Numeric threshold or option (see Details).

`test_ferralic_texture` *Ferralic texture: sandy loam or finer (same predicate as argic)*

Description

Ferralic texture: sandy loam or finer (same predicate as argic)

Usage

```
test_ferralic_texture(h, candidate_layers = NULL)
```

Arguments

- `h` Numeric threshold or option (see Details).
- `candidate_layers` Numeric threshold or option (see Details).

v0.9.70 morphological fallback (opt-in)

Many BDsolos / SOTERLAC profiles do not record `clay_pct`, `silt_pct`, `sand_pct` on the deep B horizon – only on the topsoil. The strict texture test then returns `NA`, and `ferralic()` cascades to NA, blocking Latossolos detection.

With `options(soilKey.ferralic_texture_morphological_fallback = TRUE)` `test_ferralic_texture()` accepts a layer as ferralic-textured when the canonical numeric test is NA *and* the layer satisfies *both*:

1. designation matches `Bw|Bo|Boi` (deeply weathered B-horizon morphology), and
2. `top_cm` > `20` (subsoil, not topsoil).

This is a conservative morphological inference: a Bw / Bo designation in a subsoil context strongly implies tropical deep-weathering, which in turn implies sandy-loam-or-finer texture in 95\ `FALSE` (canonical WRB behaviour preserved).

test_ferralic_thickness *Ferralic minimum thickness >= 30 cm (WRB 2022)*

Description

Wraps test_minimum_thickness.

Usage

```
test_ferralic_thickness(h, min_cm = 30, candidate_layers = NULL)
```

Arguments

h	Numeric threshold or option (see Details).
min_cm	Numeric threshold or option (see Details).
candidate_layers	Numeric threshold or option (see Details).

test_fe_dcb_above *Test for high free-iron content (fe_dcb_pct >= threshold)*

Description

Default 4% (an indicator of strong red colour and Fe-richness; used as a v0.3 simplified marker for nitic horizon's typical Fe content).

Usage

```
test_fe_dcb_above(h, min_pct = 4, candidate_layers = NULL)
```

Arguments

h	Numeric threshold or option (see Details).
min_pct	Numeric threshold or option (see Details).
candidate_layers	Numeric threshold or option (see Details).

`test_fluvic_stratification`
Test for fluvic stratification: irregular OC pattern + texture variability across consecutive horizons

---

Description

v0.3 simplified: returns TRUE when (a) at least 3 layers within the upper 100 cm exist, AND (b) clay_pct varies by >= 8 percentage points across consecutive layers (indicating depositional alternation), AND (c) OC does not decrease monotonically with depth.

Usage

```
test_fluvic_stratification(h, max_top_cm = 100, min_clay_swing = 8)
```

Arguments

`h`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).
`min_clay_swing`	Numeric threshold or option (see Details).

`test_gleyic_features` *Test for gleyic redoximorphic features within top 50 cm*

Description

Two evidence paths (any qualifies):

1. **Mottle percent** (primary): explicit `redoximorphic_features_pct` >= `min_redox_pct` (default 5\ is the v0.2 path.
2. **Gleyic Munsell hue** (v0.9.61, secondary): the horizon Munsell hue matches gleyic patterns (N / 5GY / 10G / 5BG / 10B etc.) AND chroma <= 2. Used when mottle percent is not reported. Common in BDsolos exports where surveyors fill matiz/valor/croma but leave mottle quantity empty.

Either path qualifies. If neither is determinable for any candidate layer (mottle pct AND hue both NA), returns NA. If both are determinable but neither passes, returns FALSE.

Usage

```
test_gleyic_features(
  h,
  max_top_cm = 50,
  min_redox_pct = 5,
  candidate_layers = NULL,
  max_chroma = 2
)
```

Arguments

- `h` Numeric threshold or option (see Details).
- `max_top_cm` Numeric threshold or option (see Details).
- `min_redox_pct` Numeric threshold or option (see Details).
- `candidate_layers` Numeric threshold or option (see Details).
- `max_chroma` Numeric threshold; gleyic-hue path requires `munsell_chroma_moist` <= `max_chroma` (default 2).

---

test_minimum_thickness

Test minimum horizon thickness

Description

For each candidate layer, checks `bottom_cm - top_cm` >= `min_cm`. Used by argic (default 7.5), ferralic (30), mollic (20), and others.

Usage

```
test_minimum_thickness(h, min_cm = 7.5, candidate_layers = NULL)
```

Arguments

- `h` Horizons data.table.
- `min_cm` Minimum thickness in cm.
- `candidate_layers` Integer vector of horizon indices to test. If NULL, all layers are tested.

---

test_mollic_base_saturation

Mollic base-saturation test (NH4OAc, pH 7, default >= 50%)

Description

Mollic base-saturation test (NH4OAc, pH 7, default >= 50%)

Usage

```
test_mollic_base_saturation(
  h,
  min_pct = 50,
  candidate_layers = NULL,
  allow_inference = TRUE
)
```

Arguments

`h` Numeric threshold or option (see Details).

`min_pct` Numeric threshold or option (see Details).

`candidate_layers`
Numeric threshold or option (see Details).

`allow_inference`
If `TRUE` (default), fall back to sum-of-cations / CEC arithmetic OR `al_sat_pct < 20` OR `ph_h2o >= 5.8` when `bs_pct` is missing.

`test_mollic_color` *Mollic Munsell color test (WRB 2022)*

Description

Moist value <= 3 AND moist chroma <= 3 AND dry value <= 5. If `munsell_value_dry` is missing, uses the conservative substitute `munsell_value_moist + 1`.

Usage

```
test_mollic_color(
  h,
  max_value_moist = 3,
  max_chroma_moist = 3,
  max_value_dry = 5,
  candidate_layers = NULL,
  allow_oc_inference = TRUE
)
```

Arguments

`h` Numeric threshold or option (see Details).

`max_value_moist`
Numeric threshold or option (see Details).

`max_chroma_moist`
Numeric threshold or option (see Details).

`max_value_dry` Numeric threshold or option (see Details).

`candidate_layers`
Optional restriction.

`allow_oc_inference`
If `TRUE` (default), accept OC \>= 1.5 % in a surface A horizon as evidence of dark colour when both moist and dry Munsell are missing.

test_mollic_organic_carbon *Mollic organic-carbon test (WRB 2022, default >= 0.6%)*

Description

Mollic organic-carbon test (WRB 2022, default >= 0.6%)

Usage

```
test_mollic_organic_carbon(h, min_pct = 0.6, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_mollic_structure *Mollic structure test (WRB 2022)*

Description

Excludes horizons that are simultaneously massive AND very hard when dry. v0.1 implementation reads `structure_grade` and `consistence_moist` as text and looks for the keyword pair.

Usage

```
test_mollic_structure(h, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_mollic_thickness *Mollic thickness test (default >= 20 cm in v0.1)*

Description

WRB 2022 has more nuanced thickness criteria depending on whether the soil overlies continuous rock at <75 cm, but the simple absolute threshold is the predominant case for non-shallow soils. Cumulative thickness across multiple contiguous mollic-qualifying horizons is a v0.2 refinement.

Usage

```
test_mollic_thickness(h, min_cm = 20, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_cm`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_oc_above *Test that organic carbon is at or above a threshold*

Description

Default 12% (histic horizon, WRB 2022 Chapter 3).

Usage

```
test_oc_above(h, min_pct = 12, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_ph_below *Test that ph_h2o is at or below a threshold*

Description

Default 5.9 (Spodic horizon supplementary criterion, WRB 2022).

Usage

```
test_ph_below(h, max_ph = 5.9, candidate_layers = NULL)
```

Arguments

h	Numeric threshold or option (see Details).
max_ph	Numeric threshold or option (see Details).
candidate_layers	Numeric threshold or option (see Details).

test_plinthite_concentration *Test for plinthite concentration above threshold (per layer)*

Description

Default 15% by volume (plinthic horizon, WRB 2022 Chapter 3). Used by plinthic.

Usage

```
test_plinthite_concentration(h, min_pct = 15, candidate_layers = NULL)
```

Arguments

h	Numeric threshold or option (see Details).
min_pct	Numeric threshold or option (see Details).
candidate_layers	Numeric threshold or option (see Details).

`test_salic_product` *Test the salic horizon EC * thickness product (WRB 2022)*

Description

Tests whether each candidate layer's product `ec_dS_m * (bottom_cm - top_cm)` reaches the canonical WRB 2022 threshold (Ch 3.1.20, p. 49):

- >= `450` dS/m * cm for the primary path (EC \>= 15);
- >= `240` dS/m * cm for the alkaline path (EC \>= 8 with pH(H2O) \>= 8.5).

The path used per layer is taken from a prior `test_ec_concentration` result (its `details[[i]]\$path` field). When no prior is supplied, every candidate is treated as "primary" and the 450 threshold is applied uniformly.

Usage

```
test_salic_product(
  h,
  min_product = 450,
  alkaline_min_product = 240,
  ec_path_lookup = NULL,
  candidate_layers = NULL
)
```

Arguments

`h` Horizons table.

`min_product` Primary product threshold (default 450).

`alkaline_min_product`
Alkaline-path product threshold (default 240).

`ec_path_lookup` Optional named list (keys = layer index as character) returning either "primary" or "alkaline" per layer – typically built by passing `test_ec_concentration(...)\$details`.

`candidate_layers`
Layer index restriction (typically the layers that already passed the primary EC gate).

`test_slickensides_present` *Test for slickensides at or above a presence level*

Description

Default accepted levels are `c("common", "many", "continuous")` (vertic features, WRB 2022). The `slickensides` column accepts `c("absent", "few", "common", "many", "continuous")`.

Usage

```
test_slickensides_present(
  h,
  levels = c("common", "many", "continuous"),
  candidate_layers = NULL
)
```

Arguments

`h`	Numeric threshold or option (see Details).
`levels`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

`test_spodic_aluminum_iron` *Test the spodic Al/Fe oxalate criterion: (al_ox + 0.5*fe_ox) >= threshold*

Description

Default 0.5% (WRB 2022 Chapter 3, Spodic horizon). Used by `spodic`.

Usage

```
test_spodic_aluminum_iron(h, min_pct = 0.5, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`min_pct`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

test_stagnic_pattern *Test for stagnic redox features (perched water signature)*

Description

Distinct from gleyic (groundwater): stagnic = redoximorphic features in some layer within the upper `max_top_cm` (default 100) AND redox in deeper layers DROPS substantially (decay to < third of the shallow value). The decay condition is what separates perched water (sits above an impermeable layer; deeper soil is not saturated) from groundwater-driven gleying (saturation continues with depth).

Usage

```
test_stagnic_pattern(h, max_top_cm = 100, min_redox_pct = 5, decay_factor = 3)
```

Arguments

`h`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).
`min_redox_pct`	Numeric threshold or option (see Details).
`decay_factor`	Numeric threshold or option (see Details).

test_texture_argic *Test sandy-loam-or-finer texture (used by argic, ferralic)*

Description

Test sandy-loam-or-finer texture (used by argic, ferralic)

Usage

```
test_texture_argic(h, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

`test_top_at_or_above` *Test that a candidate layer starts at or above a top_cm threshold*

Description

Used to require surface contact (default top_cm <= 0, i.e., layer must reach the surface) or near-surface presence.

Usage

```
test_top_at_or_above(h, max_top_cm = 0, candidate_layers = NULL)
```

Arguments

`h`	Numeric threshold or option (see Details).
`max_top_cm`	Numeric threshold or option (see Details).
`candidate_layers`	Numeric threshold or option (see Details).

`texture_class_from_pct` *NRCS texture-class shorthand from clay / silt / sand percent*

Description

aqp's `getArgillicBounds()` requires an NRCS texture class column (e.g. "SCL", "C", "CL", "FS"). soilKey horizons only carry the percent fractions; this helper derives the class from the standard USDA texture triangle.

Usage

```
texture_class_from_pct(clay, silt, sand)
```

Arguments

`clay`	Numeric vector of clay percent (0-100).
`silt`	Numeric vector of silt percent.
`sand`	Numeric vector of sand percent. (clay + silt + sand should sum to ~100; mild deviations are tolerated.)

Details

Returns the standard NRCS abbreviation:

COS	Coarse sand
S	Sand
FS	Fine sand
VFS	Very fine sand
LS	Loamy sand
LFS	Loamy fine sand
SL	Sandy loam
FSL	Fine sandy loam
L	Loam
SIL	Silt loam
SI	Silt
SCL	Sandy clay loam
CL	Clay loam
SICL	Silty clay loam
SC	Sandy clay
SIC	Silty clay
C	Clay

Implementation follows the canonical USDA texture triangle; vector- ised over the input. NA in / NA out.

Value

Character vector of NRCS texture class abbreviations.

`thaptic_subgroup_usda` *Thaptic Subgroup helper (Andisols) Pass when, between 25 and 100 cm, a 10+ cm layer with OC > 3.0% and mollic colors exists, underlying lighter horizons.*

Description

Thaptic Subgroup helper (Andisols) Pass when, between 25 and 100 cm, a 10+ cm layer with OC > 3.0% and mollic colors exists, underlying lighter horizons.

Usage

```
thaptic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`thapto_humic_usda` *Thapto-Humic Subgroup helper*

Description

Pass when a buried layer meets criteria for histic, mollic, umbric, or melanic epipedon within 200 cm of the soil surface, OR buried O and dark-colored A horizons (V <= 3 moist, combined thickness >= 20 cm, OC >= 1 percent Holocene-age) within 200 cm (KST 13ed, p 189-191).

Usage

```
thapto_humic_usda(
  pedon,
  max_top_cm = 200,
  min_thickness_cm = 20,
  min_oc_pct = 1
)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Default 200.
`min_thickness_cm`	Default 20.
`min_oc_pct`	Default 1.0.

Details

Implementation detects buried horizons via designation containing 'b' (KST notation for buried) AND dark color (V <= 3) within 200 cm.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 9 various.

thionic — *Thionic horizon (WRB 2022): post-oxidation acid sulfate horizon. Requires sulfidic_s_pct >= 0.01 AND pH(H2O) <= 4.*

Description

Thionic horizon (WRB 2022): post-oxidation acid sulfate horizon. Requires sulfidic_s_pct >= 0.01 AND pH(H2O) <= 4.

Usage

```
thionic(pedon, min_thickness = 15, max_pH = 4, min_sulfidic_s = 0.01)
```

Arguments

pedon	A PedonRecord.
min_thickness	Numeric threshold or option (see Details).
max_pH	Numeric threshold or option (see Details).
min_sulfidic_s	Numeric threshold or option (see Details).

train_pls_from_ossl — *Train pre-trained PLSR models from an OSSL library*

Description

Iterates over `properties` and fits one PLSR model per target against the OSSL spectra in `ossl_library$Xr`, with internal cross-validation to pick the optimal number of components per property. The returned list is a drop-in replacement for the `ossl_models` argument of `predict_ossl_pretrained` and `fill_from_spectra`.

Usage

```
train_pls_from_ossl(
  ossl_library,
 properties = c("clay_pct", "sand_pct", "silt_pct", "cec_cmol", "ph_h2o", "oc_pct"),
  ncomp_max = 20L,
  validation = c("CV", "LOO", "none"),
  segments = 10L,
  preprocess = "snv+sg1",
  min_n = 50L,
  verbose = TRUE
)
```

Arguments

- `ossl_library` A list with two named elements: `Xr` (numeric matrix of training spectra) and `Yr` (data.frame keyed by property name, one row per training spectrum). See `ossl_library_template`.
- `properties` Character vector of column names in `ossl_library$Yr` to train models for. Defaults to the six core soil properties exposed by OSSL.
- `ncomp_max` Integer. Upper bound on the number of PLS components to consider during cross-validation. Defaults to 20.
- `validation` One of `"CV"` (default, k-fold), `"LOO"` (leave-one-out, slow), `"none"` (uses `ncomp_max` components without selection).
- `segments` Number of CV segments when `validation = "CV"`. Default 10.
- `preprocess` Pre-processing label passed to `preprocess_spectra`. Stored on the trained models so `predict_from_spectra` can reapply it.
- `min_n` Minimum number of valid training samples (after dropping rows with non-finite y or X). Properties below this threshold are skipped with a warning. Default 50.
- `verbose` If `TRUE` (default), prints a per-property summary on completion.

Details

Spectra are pre-processed inside the function (default `"snv+sg1"`); the same preprocessing is used downstream by `predict_from_spectra` so the user does not have to remember which transform was applied at training time.

Value

A named list of `soilKey_pls_model` objects, one per successfully trained property. Carries `trained_at`, `soilKey_version` and `preprocess` attributes for provenance.

Examples

```
if (requireNamespace("pls", quietly = TRUE)) {
  # Toy training run on the bundled synthetic library:
  data(ossl_demo_sa)
  models <- try(train_pls_from_ossl(ossl_demo_sa,
                                    properties = c("clay_pct", "ph_h2o"),
                                    min_n = 10L,
                                    validation = "none"),
                silent = TRUE)
}
```

`tsitelic` *Tsitelic horizon (WRB 2022 Ch 3.1)*

Description

From Georgian *tsiteli* = red. A red colour-defined horizon formed on weathered basalt or similar Fe-rich parent material in Caucasian / Mediterranean settings. Used by the Cambisols key (Ch 4 p 123, criterion 4) and by the Tsitelic qualifier.

Usage

```
tsitelic(pedon, min_thickness = 10)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Numeric threshold or option (see Details).

Details

Diagnostic criteria (v0.3.5 simplification):

- Munsell hue \<= 2.5YR (i.e. 2.5YR, 10R, 7.5R, 5R, 2.5R) AND value \<= 4 (moist) AND chroma \>= 4 (moist);
- evidence of soil formation (cambic-style criterion 3) proxied by clay \>= 8% AND `structure_grade` not "single grain" / "massive";
- thickness \>= 10 cm.

`turbic_subgroup_usda` *Turbic Subgroup helper (Gelods) Pass when gelic materials are present within 200 cm. Implementation: cryoturbation + permafrost within 200 cm.*

Description

Turbic Subgroup helper (Gelods) Pass when gelic materials are present within 200 cm. Implementation: cryoturbation + permafrost within 200 cm.

Usage

```
turbic_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`ultic_subgroup_usda` *Ultic Subgroup helper: argillic or kandic (any BS).*

Description

Ultic Subgroup helper: argillic or kandic (any BS).

Usage

```
ultic_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`ultisol_qualifying_usda` *Ultisol Order qualifier (USDA, KST 13ed, Ch 2) Pass when argillic OR kandic horizon present + BS < 35% in some part of the upper 200 cm.*

Description

Ultisol Order qualifier (USDA, KST 13ed, Ch 2) Pass when argillic OR kandic horizon present + BS < 35% in some part of the upper 200 cm.

Usage

```
ultisol_qualifying_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`ultisol_usda` *Ultisols (USDA Cap 15): argillic/kandic horizon + base saturation < 35%.*

Description

v0.9.17 graceful BS handling: when `bs_pct` is missing in the argillic layers, the diagnostic falls back to two equivalent indirect criteria before failing:

- `al_sat_pct` >= `50` (high Al saturation mathematically forces BS < 50, and BS < 35 in essentially all tropical soils with this profile);
- `ph_h2o` < `5.0` (the empirical threshold below which BS exceeds 35 in fewer than 5

The fallback only fires when the direct measurement is missing, so lab-grade profiles always use the canonical KST 13ed gate.

Usage

```
ultisol_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

`umbric_epipedon_usda` *Umbric epipedon (USDA Soil Taxonomy, 13th edition)*

Description

A thick, dark-colored, base-poor (BS < 50 percent) mineral surface horizon. Differs from mollic in low base saturation; qualifies the Humults / Humic / Umbric subgroups in many orders.

Usage

```
umbric_epipedon_usda(pedon, max_bs = 50, min_oc_pct = 0.6)
```

Arguments

`pedon`	A `PedonRecord`.
`max_bs`	Maximum BS (default 50 – "less than 50 percent").
`min_oc_pct`	Minimum OC (default 0.6).

Details

KST 13ed required characteristics (Ch. 3, pp 18-20):

- Color: same as mollic (V<=3 moist, V<=5 dry, chroma<=3);
- Base saturation (NH4OAc) < 50 percent in some part;
- Organic carbon >= 0.6 percent (or 0.6 absolute > C);
- Thickness: same rules as mollic (18 / 25 / 10 cm);
- Structure: peds <= 30 cm OR rupture-resistance <= moderately hard.

Value

A `DiagnosticResult`.

References

Soil Survey Staff (2022), KST 13ed, Ch. 3, pp 18-20.

`umbric_horizon` *Umbric horizon (WRB 2022)*

Description

Tests for the umbric horizon – a thick, dark, organic-rich surface horizon like mollic, but with low base saturation (< 50%). Diagnostic of Umbrisols.

Usage

```
umbric_horizon(
  pedon,
  min_thickness = 20,
  min_oc = 0.6,
  max_bs = 50,
  surface_top_cm = 5
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_thickness`	Minimum thickness (cm; default 20).
`min_oc`	Minimum SOC % (default 0.6).
`max_bs`	Maximum base saturation % (default 50; profile must be BELOW this).
`surface_top_cm`	Maximum top_cm for surface-related layers (default 5).

Details

Implementation reuses every mollic sub-test except the BS test, which is inverted via `test_bs_below`.

Value

A DiagnosticResult.

References

IUSS Working Group WRB (2022), Chapter 3, Umbric horizon.

---

umbric_subgroup_usda — *Umbric Subgroup helper (in Spodosols) Pass when umbric_epipedon_usda passes.*

Description

Umbric Subgroup helper (in Spodosols) Pass when umbric_epipedon_usda passes.

Usage

```
umbric_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

usda_to_wrb_rsg — *USDA Soil Taxonomy <-> WRB Reference Soil Group correlation table*

Description

Returns the single most-common WRB RSG for a given USDA Order + optional Suborder. Based on IUSS WRB (2022) Annex 6.

Usage

```
usda_to_wrb_rsg(usda_order, usda_suborder = NULL)
```

Arguments

usda_order	Character vector of USDA Order names. Case- insensitive; trailing 's' stripped (e.g.\ both "Mollisols" and "Mollisol" accepted).
usda_suborder	Optional character vector of USDA Suborder names (case-insensitive) used to refine the mapping. Same length as `usda_order` or recycled.

Value

Character vector of WRB Reference Soil Group names (singular, no plural 's'). NA for unrecognised inputs.

Caveat

This is a "best-guess" cross-walk for benchmark validation only. Real-world correlation requires per-pedon evaluation of WRB diagnostic horizons. Use this function to derive a reasonable *expected* WRB classification from a USDA-classified pedon (e.g.\ from KSSL/NASIS) so that `classify_wrb2022()` can be validated against an external taxonomy on the same profiles.

References

IUSS Working Group WRB (2022). *World Reference Base for Soil Resources*, 4th edition, Annex 6. International Union of Soil Sciences, Vienna.

Examples

```
usda_to_wrb_rsg("Mollisols")
#> "Phaeozem"
usda_to_wrb_rsg("Aridisols", "Salids")
#> "Solonchak"
usda_to_wrb_rsg(c("Spodosols", "Oxisols", "Vertisols"))
#> c("Podzol", "Ferralsol", "Vertisol")
```

`validate_pedon_json` *Validate a PedonRecord against the JSON schema*

Description

Convenience wrapper that converts a `PedonRecord` (or a compatible list) to JSON and validates it via `jsonvalidate::json_validate` against the canonical schema returned by `pedon_json_schema`.

Usage

```
validate_pedon_json(x)
```

Arguments

`x`	A `PedonRecord` or a list with the same shape.

Details

Use this BEFORE calling `classify_*` when ingesting data from external systems (web APIs, ETL pipelines, multimodal extraction) to catch schema violations early.

Value

A logical scalar (TRUE when valid). Validation errors appear as the errors attribute when FALSE.

Examples

```
if (requireNamespace("jsonlite", quietly = TRUE) &&
      requireNamespace("jsonvalidate", quietly = TRUE)) {
  p <- make_ferralsol_canonical()
  validate_pedon_json(p)
}
```

---

vermic_subgroup_usda   *Vermic Subgroup helper (Vermudolls / Vermustolls) Pass when worm_holes_pct >= 50% in some horizon (KST 13ed worm burrow criterion).*

Description

Vermic Subgroup helper (Vermudolls / Vermustolls) Pass when worm_holes_pct >= 50% in some horizon (KST 13ed worm burrow criterion).

Usage

```
vermic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

---

vertic_aridisol_usda   *Vertic Aridisols helper – delegates to vertic_subgroup_usda*

Description

Vertic Aridisols helper – delegates to vertic_subgroup_usda

Usage

```
vertic_aridisol_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`vertic_horizon` *Vertic horizon (WRB 2022 Ch 3.1)*

Description

Stricter than the vertic *properties*: the vertic *horizon* requires \>= 30% clay throughout, slickensides at \>= "common" level, AND shrink-swell cracks \>= 0.5 cm wide. Used by Vertisols. v0.9.19 adds an OR-alternative COLE-based linear-extensibility path: summed (`cole_value * thickness`) over the upper 100 cm \>= 6 cm passes the diagnostic even when slickensides + cracks are not recorded (KST 13ed Ch 16 LE alternative, p 343).

Usage

```
vertic_horizon(
  pedon,
  min_clay = 30,
  min_thickness = 25,
  min_le_cm = 6,
  le_max_depth_cm = 100
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_clay`	Numeric threshold or option (see Details).
`min_thickness`	Numeric threshold or option (see Details).
`min_le_cm`	Minimum LE sum (cm) for the COLE-based path (default 6, per KST 13ed Ch 16).
`le_max_depth_cm`	Depth window (cm) for the COLE-based path (default 100).

v0.9.72 designation morphological inference (opt-in)

Field-described Brazilian Vertissolos profiles (e.g.\ the Embrapa Redape curated dataset) encode vertic morphology via a `v` master-letter modifier in the horizon designation (`Bv`, `Bvk1`, `Cv`, `Cvz`) without recording `slickensides` class or `shrink_swell_cracks_cm` as numeric inputs. With `options(soilKey.vertic_designation_inference = TRUE)` the function accepts a layer as vertic when the canonical and COLE paths both fail or are NA AND the layer has `clay_pct >= min_clay` AND its designation matches a `v` master-letter modifier. Default is `FALSE`.

`vertic_properties` *Vertic properties (WRB 2022)*

Description

Tests whether any horizon shows vertic properties – shrink-swell clay behaviour evidenced by slickensides, wedge-shaped peds, and deep cracks. Diagnostic for Vertisols.

Usage

```
vertic_properties(
  pedon,
  min_clay = 30,
  min_thickness = 25,
  slickenside_levels = c("common", "many", "continuous")
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_clay`	Minimum clay percent (default 30, per WRB 2022).
`min_thickness`	Minimum thickness (cm) of the vertic layer (default 25 per WRB 2022 Ch 3.2.x).
`slickenside_levels`	Vector of `slickensides` values accepted as evidence (default `c("common", "many","continuous")`).

Details

Sub-tests:

- `test_clay_above` – clay >= 30%
- `test_slickensides_present` – slickensides at or above the "common" level
- `test_minimum_thickness` – combined vertic layer thickness >= 25 cm (v0.3.1 added per WRB 2022)

v0.3.1: thickness gate added. Limitations remaining: WRB also accepts deep cracks (>= 1 cm wide extending from the surface to >= 50 cm depth, when soil is dry) and wedge-shaped peds as alternative evidence; this implementation requires clay + slickensides. The "after mixing of upper 18 cm" clause from WRB is still deferred.

Value

A `DiagnosticResult`.

References

IUSS Working Group WRB (2022), Chapter 3.2 – Vertic properties.

vertic_subgroup_usda — *Vertic Subgroup helper (USDA, KST 13ed)*

Description

Pass when EITHER:

- Cracks within 125 cm of the mineral soil surface that are >= 5 mm wide through a thickness >= 30 cm AND slickensides or wedge-shaped peds in a layer >= 15 cm thick within 125 cm; OR
- Linear extensibility (LE) >= 6.0 cm between surface and 100 cm (or to a densic/lithic/paralithic contact).

Usage

```
vertic_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation: tests cracks_width_cm >= 0.5 AND cracks_depth_cm >= 30 AND slickensides present, OR sum(thickness * cole_value) >= 6 cm.

Value

A DiagnosticResult.

vertisol — *Vertisol RSG gate (WRB 2022 Ch 4, p 101)*

Description

WRB-canonical: vertic horizon \<= 100 cm AND \>= 30% clay between the surface and the vertic horizon throughout AND shrink-swell cracks that start at the surface (or below a plough layer / below a self- mulching surface / below a surface crust) and extend to the vertic horizon.

Usage

```
vertisol(pedon)
```

Arguments

pedon	A PedonRecord.

Details

v0.3.4 enforces (1) vertic horizon, (2) all overlying layers \>= 30% clay, and (3) shrink-swell cracks that start within the upper 20 cm. "Cracks extending to the vertic horizon" is enforced indirectly by the test_shrink_swell_cracks test that already requires an explicit `cracks_width_cm` value.

Value

A `DiagnosticResult`.

`vertisol_qualifying_usda` *Vertisol Order qualifier (USDA, KST 13ed, Ch 2 / Ch 3 vertic horizon) Pass when a vertic horizon (clay >= 30, cracks, slickensides, LE) is present. Delegates to WRB* `vertic_horizon`.

Description

Vertisol Order qualifier (USDA, KST 13ed, Ch 2 / Ch 3 vertic horizon) Pass when a vertic horizon (clay >= 30, cracks, slickensides, LE) is present. Delegates to WRB `vertic_horizon`.

Usage

```
vertisol_qualifying_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

`vertisol_usda` *Vertisols (USDA Cap 16): slickensides + cracks. Delegates to vertic_horizon.*

Description

Vertisols (USDA Cap 16): slickensides + cracks. Delegates to vertic_horizon.

Usage

```
vertisol_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

vertissolo *Vertissolos (SiBCS Cap 4, p 112; conceito Cap 3, p 105-106)*

Description

Horizonte vertico iniciando \<= 100 cm + clay \>= 30% nos 20 cm superficiais + fendas verticais + ausencia de contato litico / petrocalcico / duripa nos 30 cm + COLE \>= 0.06.

Usage

```
vertissolo(pedon)
```

Arguments

pedon	A PedonRecord.

vertissolo_ebanico *Vertissolos Ebanicos (Cap 17): caracter ebanico em B (cores escuras dominantes).*

Description

Vertissolos Ebanicos (Cap 17): caracter ebanico em B (cores escuras dominantes).

Usage

```
vertissolo_ebanico(pedon)
```

Arguments

pedon	A PedonRecord.

vertissolo_haplico *Vertissolos Haplicos (catch-all).*

Description

Vertissolos Haplicos (catch-all).

Usage

```
vertissolo_haplico(pedon)
```

Arguments

pedon	A PedonRecord.

`vertissolo_hidromorfico` *Vertissolos Hidromorficos (Cap 17): horizonte glei OR caracter redoxico.*

Description

Vertissolos Hidromorficos (Cap 17): horizonte glei OR caracter redoxico.

Usage

```
vertissolo_hidromorfico(pedon)
```

Arguments

pedon	A `PedonRecord`.

`vitrandic_subgroup_usda` *Vitrandic Subgroup helper (USDA, KST 13ed)*

Description

Pass when, throughout one or more horizons with total thickness >= 18 cm within 75 cm of the surface, BOTH:

- More than 35% (volume) particles >= 2 mm of which > 66% are cinders/pumice; OR fine-earth has >= 30% particles 0.02-2 mm AND >= 5% volcanic glass (in 0.02-2 mm); AND
- (Al + 0.5 * Fe) * 60 + volcanic_glass_pct >= 30.

KST 13ed, Ch 9 various.

Usage

```
vitrandic_subgroup_usda(pedon)
```

Arguments

pedon	A `PedonRecord`.

Details

Implementation simplified to the volcanic-glass branch: volcanic_glass_pct >= 5 AND (Al + 0.5 * Fe) * 60 + volcanic_glass_pct >= 30.

Value

A `DiagnosticResult`.

`vitrand_qualifying_usda`
Vitrands qualifier (Cap 6, pp 117-118) Pass when 1500 kPa water retention < 15% (air-dried) and < 30% (undried) throughout 60%+ of the thickness. v0.8 proxy: uses water_content_1500kpa < 15%.

Description

Vitrands qualifier (Cap 6, pp 117-118) Pass when 1500 kPa water retention < 15% (air-dried) and < 30% (undried) throughout 60%+ of the thickness. v0.8 proxy: uses water_content_1500kpa < 15%.

Usage

```
vitrand_qualifying_usda(pedon, max_top_cm = 60)
```

Arguments

`pedon`	A `PedonRecord`.
`max_top_cm`	Numeric threshold or option (see Details).

`vitric_properties` *Vitric properties (WRB 2022 Ch 3.2.16)*

Description

Volcanic glass \>= 5% in 0.02-2 mm fraction, Al_ox + 1/2 Fe_ox \>= 0.4%, phosphate retention \>= 25%.

Usage

```
vitric_properties(
  pedon,
  min_glass_pct = 5,
  min_alfe = 0.4,
  min_p_retention = 25
)
```

Arguments

`pedon`	A `PedonRecord`.
`min_glass_pct`	Numeric threshold or option (see Details).
`min_alfe`	Numeric threshold or option (see Details).
`min_p_retention`	Numeric threshold or option (see Details).

vitric_subgroup_usda — *Vitric Subgroup helper (Andisols) Pass when volcanic_glass_pct >= 30 in a 25+ cm layer within 100 cm.*

Description

Vitric Subgroup helper (Andisols) Pass when volcanic_glass_pct >= 30 in a 25+ cm layer within 100 cm.

Usage

```
vitric_subgroup_usda(pedon)
```

Arguments

pedon	A PedonRecord.

vlm_pick_provider — *Pick the best available VLM provider*

Description

Selects a provider based on what is reachable in the user's environment, in this preference order: local Ollama (if `ollama_is_running()`), then Anthropic, OpenAI, and Google (each requires the relevant `*_API_KEY` environment variable). Errors with an actionable installation / API-key hint when no provider is reachable.

Usage

```
vlm_pick_provider(verbose = TRUE)
```

Arguments

verbose	If `TRUE` (default), emits a one-line `cli` message explaining the chosen provider.

Value

Character scalar: one of `"ollama"`, `"anthropic"`, `"openai"`, `"google"`.

vlm_provider *Construct a VLM provider chat object*

Description

Returns an ellmer chat object configured for the given provider, ready to be passed to the extraction functions (extract_horizons_from_pdf, etc.). The chat object wraps API credentials and model selection; it does not itself send any request.

Usage

```
vlm_provider(
  name = c("auto", "anthropic", "openai", "google", "ollama"),
  model = NULL,
  ...
)
```

Arguments

name	Provider name. One of "anthropic" (Claude), "openai" (GPT-4o family), "google" (Gemini), "ollama" (local).
model	Optional model identifier; defaults to default_model(name).
...	Additional arguments forwarded to the corresponding ellmer::chat_* constructor (e.g. system_prompt, api_key, base_url, params).

Details

This is purely a convenience wrapper: it picks a default model per provider and forwards remaining arguments (e.g. system_prompt, api_key) to the underlying ellmer constructor. ellmer must be installed.

Value

An ellmer Chat object exposing a $chat() method for sending prompts.

Local-first option

Passing name = "ollama" runs every extraction locally via an Ollama server (default gemma4:e4b, Gemma 4 edge with multimodal text+image+audio support). No data leaves the machine, which is the recommended setting for sensitive field descriptions (e.g. governmental surveys, indigenous land studies) where institutional independence and data sovereignty matter. Pull the model first:

```
ollama pull gemma4:e4b      # ~3 GB edge variant (default)
ollama pull gemma4:31b      # frontier dense variant
ollama pull gemma3:27b      # earlier generation, still solid
```

Then start an Ollama server (ollama serve) and the chat object returned here will dispatch over HTTP locally.

Examples

```
# Each provider needs either an API key (cloud) or a running daemon
# (Ollama); the example no-ops on CRAN when neither is available.
if (nzchar(Sys.getenv("ANTHROPIC_API_KEY"))) {
  provider <- try(vlm_provider("anthropic"), silent = TRUE)
}
if (interactive()) {
  # Local Gemma 4 edge model -- default, ~3 GB, runs anywhere
  provider <- try(vlm_provider("ollama"), silent = TRUE)

  # Local Gemma 4 frontier dense model -- best quality
  provider <- try(vlm_provider("ollama", model = "gemma4:31b"),
                  silent = TRUE)
}
```

`wassent_qualifying_usda` *Wassent Suborder qualifier (subaqueous Entisol). Pass when site$water_table_cm_above_surface > 0 (water column permanently above the surface).*

Description

Wassent Suborder qualifier (subaqueous Entisol). Pass when site$water_table_cm_above_surface > 0 (water column permanently above the surface).

Usage

```
wassent_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

`wassist_qualifying_usda` *Wassists Suborder qualifier (KST 13ed, Ch 10, p 203)*

Description

Histosols having a "field-observable water table 2 cm or more above the soil surface for more than 21 hours of each day in all years." Diagnostic for the Wassists suborder.

Usage

```
wassist_qualifying_usda(pedon)
```

Arguments

pedon	A PedonRecord.

Details

Implementation: pass when site$water_table_cm_above_surface is provided and >= 2 (positive = above surface).

Value

A DiagnosticResult.

---

wrb06_code_to_rsg *WRB 2006 RSG code -> 2022 RSG name*

Description

AfSP ships WRB 2006 RSG codes (2-letter, e.g.\ LV, AC, AR). The 2-letter codes are stable across WRB editions (2006 -> 2022); only a handful of qualifier names changed. This helper maps the codes to the WRB 2022 RSG names that classify_wrb2022 emits.

Usage

```
wrb06_code_to_rsg(code)
```

Arguments

code	Character vector of WRB 2006 codes.

Value

Character vector of singular WRB 2022 RSG names; NA for unrecognised codes.

`wrb2022_canonical` *WRB 2022 canonical reference (parsed IUSS Working Group WRB 2022)*

Description

Convenience wrapper for `canonical_reference("WRB_4th_2022")`. Returns a 3-element list:

- `$rsg` (118 obs): Reference Soil Group + criteria text
- `$pq` (661 obs): principal qualifiers per RSG
- `$sq` (1167 obs): supplementary qualifiers per RSG

Usage

```
wrb2022_canonical(prefer_pkg = TRUE)
```

Arguments

`prefer_pkg`	If `TRUE` (default), prefer the installed SoilTaxonomy package over the vendored copy. Set to `FALSE` to force the vendored copy (e.g. for reproducibility of a specific soilKey release).

Details

Source: NCSS-tech `SoilTaxonomy` R package. Original: IUSS Working Group WRB (2022). *World Reference Base for Soil Resources*, 4th edition.

`xanthic_subgroup_usda` *Xanthic Subgroup helper (Oxisols) Pass when 50%+ colors have hue >= 7.5YR AND value >= 6 in B horizons.*

Description

Xanthic Subgroup helper (Oxisols) Pass when 50%+ colors have hue >= 7.5YR AND value >= 6 in B horizons.

Usage

```
xanthic_subgroup_usda(pedon)
```

Arguments

`pedon`	A `PedonRecord`.

yermic_properties *Yermic properties (WRB 2022 Ch 3.2.17) – per-pedon test wrapping* `test_yermic_surface`.

Description

Yermic properties (WRB 2022 Ch 3.2.17) – per-pedon test wrapping `test_yermic_surface`.

Usage

```
yermic_properties(pedon)
```

Arguments

pedon	A `PedonRecord`.

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