KEY FOR CLASSIFYING GELISOLS OF ANTARCTICA WITH REFERENCE SOIL DATA

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The purpose of this document is to assist researchers unfamiliar with *Soil Taxonomy* (Soil Survey Staff, 1999) to classify soils of Antarctica. A key is provided that is based on Chapter 9, Gelisols, in the ninth edition of Keys to Soil Taxonomy (Soil Survey Staff, 2006) that is modified for Antarctica. Reference soils from the published literature are provided, along with digital images, to assist in classification of Antarctic Gelisols.

Gelisols are the permafrost-affected soils that occur throughout the zone of continuous permafrost in Antarctica (ca. >67ºS) (Bockheim, 1995). Gelisols are also dominant in the zones of discontinuous or sporadic permafrost at the latitudes 60 to 67ºS. Gelisols are of limited extent in the subantarctic islands and occur only at the highest elevations. Other soil orders may occur in subantarctic islands north of 60ºS, including Andisols, Entisols, Histosols, and Inceptisols. Keys to Soil Taxonomy (KST) should be consulted for classifying these non-permafrost-affected soils.

In most cases, the reference soils were classified by the authors. However, in a few cases (reference soil #17, 22, 33, 33, and 39), I classified the soils on the basis of the soil descriptions and analytical data provided. To classify Antarctic soils, it is important soil horizons be identified, particularly those that are cryoturbated. The key has been simplified relative to that in KST; the latter document should be consulted for detailed information.

Keys to Classifying Gelisols of Antarctica

Gelisols are soils that have

1. Permafrost within 100 cm of the soil surface; or
2. Gelic materials, defined as mineral or organic soil materials that show cryoturbation, cryodesiccation and/or ice segregation in the active layer (seasonal thaw layer) and/or upper part of the permafrost, within 100 cm of the soil surface and permafrost within 200 cm of the soil surface.

Key to Suborders

AA. Gelisols that have organic materials occupying 80% or more by volume of the upper 50 cm or over massive ice or bedrock

Histels, p. 2

AB. Other Gelisols that show cryoturbation in the form of irregular, broken, or distorted horizon boundaries, involutions, the accumulation of organic matter on top of permafrost, ice or sand wedges, and oriented rock fragments (see Bockheim and Tarnocai, 1998 for further information on cryoturbation)

Turbels, p. 12

AC. Other Gelisols

Orthels, p. 5

Histels

Key to Great Groups

AAA. Histels that are saturated with water for less than 30 cumulative days during normal years.

Folistels, p. 3

AAB. Other Histels that are saturated with water for 30 or more cumulative days and have a glacic layer (layer of massive ice $\geq$30 cm thick) and less than 75% by volume of *Sphagnum* fibers.

Glacistels, p. 3

AAC. Other Histels that have dominantly fibric (poorly decomposed) organic fibers.

Fibristels, p. 2

AAD. Other Histels that have dominantly hemic (organic materials intermediate in decomposition) organic fibers.

Hemistels, p. 4

AAE. Other Histels (that have highly decomposed, "mucky" organic fibers).

Sapristels, p. 4

Fibristels

Key to subgroups

AACA. Fibristels that have bedrock within 100 cm of the soil surface.

Lithic Fibristels (Ref. #1)

AACB. Other Fibristels that have a mineral layer 30 cm or more thick within 100 cm of the soil surface.

Terric Fibristels

AACC. Other Fibristels that have one layer 5 cm thick or two or more layers of any thickness within 100 cm of the soil surface.

Fluvaquentic Fibristels

AACD. Other Fibristels in which 75% or more of the fibric material is derived from *Sphagnum*.

Sphagnic Fibristels

AACE. Other Fibristels.

Typic Fibristels

Note: members of this great group occur in the South Shetland and South Orkney Islands (Everett, 1976; Beyer et al., 1997; Michel et al., 2006).

Folistels

Key to Subgroups

AAAA. Folistels that have bedrock within 50 cm of the soil surface.

Lithic Folistels (Ref. #2)

AAAB. Other Folistels that have massive ice >30 cm in thickness within 100 cm of the soil surface.

Glacic Folistels

AAAC. Other Folistels.

Typic Folistels

Note: members of this great group occur in the South Orkney Islands and in Wilkes Land, East Antarctica (Beyer, 2000).

Glacistels

Key to Subgroups

AABA. Glacistels that have more thickness of hemic materials than any other kind of organic soil material in the upper 50 cm.

Hemic Glacistels

AABB. Other Glacistels that have more thickness of sapric materials than any other kind of organic soil material in the upper 50 cm.

Sapric Glacistels

AABC. Other Glacistels.

Typic Glacistels

Note: members of this great group have not been reported in Antarctica.

Hemistels

Key to Subgroups

AADA. Hemistels that have bedrock within 100 cm of the soil surface.

Lithic Hemistels (Ref. #3)

AADB. Other Hemistels that have a mineral layer 30 cm or more thick within 100 cm of the soil surface.

Terric Hemistels

AADC. Other Hemistels that have, within the organic materials, either one mineral layer 5 cm or more thick or two or more layers of any thickness within 100 cm of the soil surface.

Fluvaquentic Hemistels

AADD. Other Hemistels.

Typic Hemistels (Ref. #4)

Note: members of this great group occur in the South Orkney Islands and in Wilkes Land, East Antarctica (Beyer, 2000).

Sapristels

Key to Subgroups

AAEA. Sapristels that have bedrock within 100 cm of the soil surface.

Lithic Sapristels

AAEB. Other Sapristels that have a mineral layer 30 cm or more thick within 100 cm of the soil surface.

Terric Sapristels

AAEC. Other Sapristels that have, within the organic materials, either one mineral layer 5 cm or more thick or two or more layers of any thickness within 100 cm of the soil surface.

Fluvaquentic Sapristels

AAED. Other Sapristels.

Typic Sapristels (Ref. #5)

Note: members of this great group occur in coastal East Antarctica (Beyer et al., 1997). In general, members of the Histel suborder occur in bedrock depressions of maritime Antarctica.

Orthels

Key to Great Groups

ACA. Orthels that have more than 40% by volume of organic materials in the upper 50 cm.

Historthels, p. 9

ACB. Other Orthels that have evidence or poor drainage (aquic conditions or redox depletions; see ST, 1999) in the upper 50 cm.

Aquorthels, p. 6

ACC. Other Orthels that have anhydrous conditions (i.e., the mean annual water-equivalent precipitation is less than 50 mm yr^{-1}; ice-cemented permafrost is not present in the upper 70 cm; the moisture content averaged over the 10-70 cm layer is $\leq$3% by weight; and the dry consistence of the 10-70 cm layer is loose to slightly hard except where a salt-cemented horizon is present).

Anhyorthels, p. 5

ACD. Other Orthels that have a mollic horizon (dark colors; high base status; $\geq$18 cm thick; see ST, 1999 for details).

Mollorthels, p. 10

ACE. Other Orthels that have an umbric horizon (dark colors; low base status; $\geq$18 cm thick; see ST, 1999 for details).

Umbrorthels, p. 11

ACF. Other Orthels that have a clay-enriched horizon derived from movement of silicate clays that has its upper boundary within 100 cm of the mineral soil surface.

Argiorthels, p. 8

ACG. Other Orthels that have, below a depth of 25 cm, less than 35% by volume of rock fragments and have a texture of loamy fine sand or coarser in the 25-100 cm layer.

Psammorthels, p. 10

ACH. Other Orthels.

Haplorthels, p. 8

Anhyorthels

Key to Subgroups

ACCA. Anhyorthels that have bedrock within 50 cm of the mineral soil surface.

Lithic Anhyorthels (Ref. #6)

ACCB. Other Anhyorthels that have a massive layer of ice ≥30 cm in thickness within 100 cm of the soil surface.

Glacic Anhyorthels (Ref. #7)

ACCC. Other Anhyorthels that have a gypsum-cemented (petrogypsic horizon; see ST, 1999) layer within 100 cm of the soil surface.

Petrogypsic Anhyorthels (Ref. #8)

ACCD. Other Anhyorthels that have a gypsic horizon (≥15 cm thick; ≥5% gypsum; product of gypsum concentration & thickness is ≥150; see ST, 1999) within 100 cm of the soil surface.

Gypsic Anhyorthels (Ref. #9)

ACCE. Other Anhyorthels that contain a horizon 15 cm or more thick with 12 cmol(-)/L in 1:5 soil:water nitrate and in which the product of its thickness (in cm) and its nitrate concentration is ≥3,500 (not officially recognized in ST).

Nitric Anhyorthels (Ref. #10)

ACCF. Other Anhyorthels with a nitric horizon that is weakly to strongly cemented or indurated (not officially recognized in ST).

Petronitric Anhyorthels (Ref. #11)

ACCG. Other Anhyorthels with a salic horizon (≥15 cm thick; EC ≥30 dS/m; product of EC & thickness is ≥900; see ST, 1999 for details) within 100 cm of the soil surface.

Salic Anhyorthels (Ref. #12)

ACCH. Other Anhyorthels with a salic horizon that is weakly to strongly cemented or indurated (not officially recognized in ST).

Petrosalic Anhyorthels (Ref. #13)

ACCI. Other Anyorthels.

Typic Anhyorthels (Ref. #14)

Note: members of the Anhyorthels are common in interior mountainous regions of Antarctica, including Dronning Maud Land, the Prince Charles Mountains in the Vestfold Hills region, the Transantarctic Mountains, and the Ellsworth Mountains.

Aquorthels

Key to Sugroups

ACBA. Aquorthels with bedrock within 50 cm of the mineral soil surface.

Lithic Aquorthels

ACBB. Other Aquorthels with a glacic layer (massive ice >30 cm thick) within 100 cm of the soil surface.

Glacic Aquorthels

ACBC. Other Aquorthels that have a sulfuric horizon or sulfidic materials (see ST, 1999 for details) within 100 cm of the soil surface.

Sulfuric Aquorthels

ACBD. Other Aquorthels that have either:

1. Organic soil materials that are discontinuous at the surface; or
2. Organic soil materials at the surface that change in thickness fourfold or more with the profile.

Ruptic-Histic Aquorthels

ACBE. Other Aquorthels that have andic properties ($\geq$18 cm thick; bulk density of $\leq$1.0 g/cm^3; Al + 1/2Fe percentages by ammonium oxalate >1.0; see ST, 1999 for details).

Andic Aquorthels

ACBF. Other Aquorthels that have properties that enable classification as vitrandic ($\geq$18 cm thick; abundant cinders or volcanic glass; see ST, 1999 for details).

Vitrandic Aquorthels

ACBG. Other Aquorthels that have a salic horizon ($\geq$15 cm thick; EC $\geq$30 dS/m; product of EC & thickness is $\geq$900; see ST, 1999 for details) within the upper 100 cm.

Salic Aquorthels

ACBH. Other Aquorthels that have less than 35% by volume rock fragments and a texture of loamy fine sand or coarser in all layers from 25-100 cm.

Psammentic Aquorthels

ACBI. Other Aquorthels that show evidence of poor drainage (aquic conditions or redox depletions; see ST, 1999) and have an irregular decrease in organic C between 25 and 100 cm.

Fluvaquentic Aquorthels

ACBJ. Other Aquorthels.

Typic Aquorthels (Ref. #15)

Argiorthels

Key to Subgroups

ACFA. Argiorthels that have bedrock within 50 cm of the surface.

Lithic Argiorthels

ACFB. Other Argiorthels that have massive ice $\geq$30 cm in thickness within 100 cm of the surface.

Glacic Argiorthels

ACFC. Other Argiorthels that have a natric horizon (see ST, 1999 for definition).

Natric Argiorthels

ACFD. Other Argiorthels.

Typic Argiorthels (Ref. #16)

Note: soils with argillic (clay-enriched) horizons are very uncommon in Antarctica and may be limited to Enderby Land (see MacNamara, 1969).

Haplorthels

Keys to Subgroups

ACHA. Haplorthels that have bedrock within 50 cm of the surface.

Lithic Haplorthels (Ref. #17)

ACHB. Other Haplorthels that have a layer of massive $\geq$30 cm in thickness within 100 cm of the surface.

Glacic Haplorthels

ACHC. Other Haplorthels that show evidence of poor drainage (aquic conditions or redox depletions; see ST, 1999) and have an irregular decrease in organic C between 25 and 100 cm.

Fluvaquentic Haplorthels

ACHD. Other Haplorthels that have evidence of poor drainage (aquic conditions or redox depletions; see ST, 1999).

Aquic Haplorthels

ACHE. Other Haplorthels that generally have an irregular decrease in organic C between 25 and 100 cm.

Fluventic Haplorthels

ACHF. Other Haplorthels that have a layer $\geq$5 cm thick demonstrating spodic properties (dark reddish brown colors; cementation by organic, aluminum, and/or iron or abundant oxalate-extractable Al + Fe; see ST, 1999 for details of spodic properties) (note: this subgroup is not recognized in ST).

Spodic Haplorthels

ACHG. Other Haplorthels.

Typic Haplorthels (Ref. #18)

Historthels

Keys to Subgroups

ACAA. Historthels that have bedrock within 50 cm of the surface.

Lithic Historthels (Ref. #19)

ACAB. Other Historthels that have a layer of massive ice $\geq$30 cm in thickness within 100 cm of the surface.

Glacic Historthels

ACAC. Other Historthels that show evidence of poor drainage (aquic conditions or redox depletions; see ST, 1999) and have an irregular decrease in organic C between 25 and 100 cm.

Fluvaquentic Historthels

ACAD. Other Historthels that generally have an irregular decrease in organic C between 25 and 100 cm.

Fluventic Historthels

ACAE. Other Historthels that have >40% by volume of organic soil materials within the upper 50 cm.

Ruptic Historthels

ACAF. Other Historthels.

Typic Historthels

Note: as with Histels, Historthels appear to be limited to slight depressions in bedrock where organic C can accumulate in maritime Antarctica. They may occur in dense penguin and other bird rookeries.

Mollorthels

Key to Subgroups

ACDA. Mollorthels that have bedrock within 50 cm of the surface.

Lithic Mollorthels

ACDB. Other Mollorthels that have a layer of massive ice ≥30 cm in thickness within 100 cm of the surface.

Glacic Mollorthels

ACDC. Other Mollorthels that have cracks >30 cm in width and wedge-shaped aggregates in the upper 125 cm (see ST, 1999).

Vertic Mollorthels

ACDD. Other Mollorthels that have andic properties (≥18 cm thick; bulk density of ≤1.0 g/cm^3; Al + 1/2Fe percentages by ammonium oxalate >1.0; see ST, 1999 for details).

Andic Mollorthels

ACDE. Other Mollorthels that have properties that enable classification as vitrandic (≥18 cm thick; abundant cinders or volcanic glass; see ST, 1999 for details).

Vitrandic Mollorthels

ACDF. Other Mollorthels that have a mollic horizon (dark colors; high base status; see ST, 1999 for details) >40 cm in thickness and a texture finer than loamy fine sand.

Cumulic Mollorthels

ACDG. Other Mollorthels that have evidence of poor drainage (aquic conditions or redox depletions; see ST, 1999).

Aquic Mollorthels

ACDH. Other Mollorthels.

Typic Mollorthels (Ref. #20)

Note: Although there have been few reports of Mollorthels, they likely occur in maritime Antarctic under *Deschampsia* grass on calcareous parent materials.

Psammorthels

Key to Subgroups

ACGA. Psammorthels that have bedrock within 50 cm of the surface.

Lithic Psammorthels

ACGB. Other Psammorthels have a layer of massive ice ≥30 cm in thickness within 100 cm of the surface.

Glacic Psammorthels

ACGC. Other Psammorthels that have a layer ≥5 cm thick demonstrating spodic properties (dark reddish brown colors; cementation by organic, aluminum, and/or iron or abundant oxalate-extractable Al + Fe; see ST, 1999 for details).

Spodic Psammorthels (Ref. #21)

ACGD. Other Psammorthels.

Typic Psammorthels (Ref. #22)

Note: Psammorthels are common on outwash and coarse-textured raised beach materials in maritime Antarctica. Spodic Psammorthels are one variant of the Antarctic "Podzol" identified at Casey Station, Wilkes Land (Beyer et al., 2000).

Umbrorthels

Key to Subgroups

ACEA. Umbrorthels that have bedrock within 50 cm of the surface.

Lithic Umbrorthels

ACEB. Other Umbrorthels that have massive ice ≥30 cm in thickness within the upper 100 cm.

Glacic Umbrorthels

ACEC. Other Umbrorthels that have cracks ≥30 cm in width and wedge-shaped aggregates in the upper 125 cm (see ST, 1999).

Vertic Umbrorthels

ACED. Other Umbrorthels that have andic properties (≥18 cm thick; bulk density of ≤1.0 g/cm^3; Al + 1/2Fe percentages by ammonium oxalate >1.0; see ST, 1999 for details).

Andic Umbrorthels

ACEE. Other Umbrorthels that have properties that enable classification as vitrandic (≥18 cm thick; abundant cinders or volcanic glass; see ST, 1999, for details).

Vitrandic Umbrorthels

ACEF. Other Umbrorthels that have an umbric horizon (dark colors; low base status) ≥40 cm in thickness.

Cumulic Umbrorthels (Ref. #23)

ACEG. Other Umbrorthels that have in one or more horizons in the upper 100 cm distinct or prominent redox concentrations (mottles) and also aquic conditions.

Aquic Umbrorthels

ACEH. Other Umbrorthels.

Typic Umbrorthels

Note: Although there have been few reports of Umbrorthels, they likely occur in maritime Antarctica under *Deschampsia* grass on acidic parent materials.

Turbels

Key to Great Groups

ABA. Turbels that have in 30% or more of the profile more than 40%, by volume, of organic materials within the upper 50 cm.

Histoturbels, p. 15

ABB. Other Turbels that have, within 50 cm of the mineral soil surface, evidence or poor drainage (aquic conditions or redox depletions; see ST, 1999) during normal years.

Aquiturbels, p. 14

ABC. Other Turbels that have anhydrous conditions (i.e., the mean annual water-equivalent precipitation is less than 50 mm yr^{-1}; ice-cemented permafrost is not present in the upper 70 cm; the moisture content averaged over the 10-70 cm layer is ≤3% by weight; and the dry consistence of the 10-70 cm layer is loose to slightly hard except where a salt-cemented horizon is present).

Anhyturbels, p. 13

ABD. Other Turbels that have a mollic horizon (dark colors; high base status; ≥18 cm thick; see ST, 1999 for details).

Molliturbels, p. 16

ABE. Other Turbels that have an umbric horizon (dark colors; low base status; ≥18 cm thick; see ST, 1999 for details).

Umbriturbels, p. 17

ABF. Other Turbels that have, below a depth of 25 cm, less than 35% by volume of rock fragments and have a texture of loamy fine sand or coarser in the 25-100 cm layer.

Psammoturbels, p. 16

ABG. Other Turbels.

Haploturbels, p. 15

Anhyturbels

Key to Subgroups

ABCA. Anhyturbels that have bedrock within 50 cm of the mineral soil surface.

Lithic Anhyturbels (Ref. #24)

ABCB. Other Anhyturbels that have a massive layer of ice $\geq$30 cm in thickness within 100 cm of the soil surface.

Glacic Anhyturbels (Ref. #25)

ABCC. Other Anhyturbels that have a gypsum-cemented (petrogypsic; see ST, 1999) horizon within 100 cm of the soil surface.

Petrogypsic Anhyturbels

ABCD. Other Anhyturbels that have a gypsic horizon ($\geq$15 cm thick; $\geq$5% gypsum; product of gypsum concentration & thickness is $\geq$150; see ST, 1999 for details) within 100 cm of the soil surface.

Gypsic Anhyturbels (Ref. #26)

ABCE. Other Anhyturbels a horizon 15 cm or more thick that contains 12 cmol(-)/L in 1:5 soil:water nitrate and in which the product of its thickness (in cm) and its nitrate concentration $\geq$3,500 (note: this subgroup is not recognized in ST).

Nitric Anhyturbels (Ref. #27)

ABCF. Other Anhyturbels with a nitric horizon that is weakly to strongly cemented or indurated (not officially recognized in ST).

Petronitric Anhyturbels (Ref. #28)

ABCG. Other Anhyturbels with a salic horizon ($\geq$15 cm thick; EC $\geq$30 dS/m; product of EC & thickness is $\geq$900; see ST, 1999 for details) within 100 cm of the soil surface.

Salic Anhyturbels (Ref. #29)

ABCH. Other Anhyturbels with a salic horizon that is weakly to strongly cemented or indurated (not officially recognized in ST).

Petrosalic Anhyturbels (Ref. #30)

ABCI. Other Anyturbels.

Typic Anhyturbels (Ref. #31)

Note: Anhyturbels are the most common soil in inland mountainous regions of Antarctica, including Dronning Maud Land, the Prince Charles Mountains in the Vestfold Hills region, the Transantarctic Mountains, and the Ellsworth Mountains.

Aquiturbels

Key to Subgroups

ABBA. Aquiturbels with bedrock within 50 cm of the mineral soil surface.

Lithic Aquiturbels (Ref. #32)

ABBB. Other Aquiturbels with a glacic layer (massive ice ≥30 cm in thickness) within 100 cm of the mineral soil surface.

Glacic Aquiturbels

ABBC. Other Aquiturbels that have a sulfuric horizon or sulfidic materials (see ST, 1999 for details) within 100 cm of the mineral soil surface.

Sulfuric Aquiturbels

ABBD. Other Aquorthels that have either:

1. Organic soil materials that are discontinuous at the surface; or
2. Organic soil materials at the surface that change in thickness fourfold or more with the profile.

Ruptic-Histic Aquiturbels (Ref. #33)

ABBE. Other Aquiturbels that have less than 35% by volume rock fragments and a texture of loamy fine sand or coarser in all layers from 25-100 cm.

Psammentic Aquiturbels (Ref. #34)

ABBF. Other Aquiturbels.

Typic Aquiturbels

Note: Aquiturbels are common in somewhat poorly drained, highly cryoturbated areas of maritime Antarctica.

Haploturbels

Key to Subgroups

ABGA. Haploturbels that have bedrock within 50 cm of the surface.

Lithic Haploturbels (Ref. #35)

ABGB. Other Haploturbels that have a layer of massive ≥30 cm in thickness within 100 cm of the surface.

Glacic Haploturbels (Ref. #36)

ABGC. Other Haploturbels that have evidence of poor drainage (aquic conditions or redox depletions; see ST, 1999).

Aquic Haploturbels

ABGD. Other Haploturbels.

Typic Haploturbels (Ref. #37)

Note: Haploturbels are among the most common soils in Antarctica and are prevalent in coastal areas of the Ross Sea region and throughout maritime Antarctica.

Histoturbels

Key to Subgroups

ABAA. Histoturbels that have bedrock within 50 cm of the surface.

Lithic Histoturbels (Ref. #38)

ABAB. Other Histoturbels that have a glacic layer in the upper 100 cm.

Glacic Histoturbels

ABAC. Other Histoturbels that have ≥40% by volume organic soil materials within the upper 50 cm.

Ruptic Histoturbels

ABAD. Other Histoturbels.

Typic Histoturbels (Ref. #39)

Note: Although there have been few reports of Histoturbels in Antarctica, they likely occur in penguin or other bird rookeries where patterned ground reflects cryoturbation.

Molliturbels

Key to Subgroups

ABDA. Molliturbels that have bedrock within 50 cm of the surface.

Lithic Molliturbels

ABDB. Other Molliturbels that have a layer of massive ice $\geq$30 cm in thickness within 100 cm of the surface.

Glacic Molliturbels

ABDC. Other Molliturbels that have cracks $\geq$30 cm in width and wedge-shaped aggregates in the upper 125 cm (see ST, 1999).

Vertic Molliturbels

ABDD. Other Molliturbels that have andic properties ($\geq$18 cm thick; bulk density of $\leq$1.0 g/cm^3; Al + 1/2Fe percentages by ammonium oxalate >1.0; see ST, 1999 for details).

Andic Molliturbels

ABDE. Other Molliturbels that have properties that enable classification as vitrandic ($\geq$18 cm thick; abundant cinders or volcanic glass; see ST, 1999 for details).

Vitrandic Molliturbels

ABDF. Other Molliturbels that have a mollic epipedon (dark colors; high base status; see ST, 1999 for details) $\geq$40 cm in thickness and a texture finer than loamy fine sand.

Cumulic Molliturbels

ABDG. Other Molliturbels that have evidence of poor drainage (aquic conditions or redox depletions; see ST, 1999).

Aquic Molliturbels

ABDH. Other Molliturbels.

Typic Molliturbels

Note: Although there have been no published reports of Molliturbels, they likely occur in maritime areas with dense *Deschampsia* grass, especially on calcareous parent materials that has been cryoturbated.

Psammoturbels

Key to Subgroups

ABFA. Psammoturbels that have bedrock within 50 cm of the surface.

Lithic Psammoturbels

ABFB. Other Psammoturbels have a layer of massive ice ≥30 cm in thickness within 100 cm of the surface.

Glacic Psammoturbels

ABFC. Other Psammoturbels that have a layer ≥5 cm thick demonstrating spodic properties (dark reddish brown colors; cementation by organic, aluminum, and/or iron or abundant oxalate-extractable Al + Fe; see ST, 1999 for details).

Spodic Psammoturbels

ABFD. Other Psammoturbels.

Typic Psammoturbels

Note: If Psammoturbels exist in Antarctica, they likely occur on outwash or coarse-textured raised beaches fed by meltwater that enables cryoturbation to occur.

Umbriturbels

Key to Subgroups

ABEA. Umbriturbels that have bedrock within 50 cm of the surface.

Lithic Umbriturbels (Ref. #40)

ABEB. Other Umbriturbels that have massive ice >30 cm in thickness within the upper 100 cm.

Glacic Umbriturbels

ABEC. Other Umbriturbels that have cracks ≥30 cm in width and wedge-shaped aggregates in the upper 125 cm (see ST, 1999).

Vertic Umbriturbels

ABED. Other Umbriturbels that have andic properties (≥18 cm thick; bulk density of ≤1.0 g/cm^3; Al + 1/2Fe percentages by ammonium oxalate >1.0; see ST, 1999 for details).

Andic Umbriturbels

ABEE. Other Umbriturbels that have properties that enable classification as vitrandic (≥18 cm thick; abundant cinders or volcanic glass; see ST, 1999 for details).

Vitrandic Umbriturbels

ABEF. Other Umbriturbels that have an umbric horizon (dark colors; low base status) ≥40 cm in thickness.

Cumulic Umbriturbels

ABEG. Other Umbriturbels that have in one or more horizons in the upper 100 cm distinct or prominent redox concentrations (mottles) and also aquic conditions for some time during normal years.

Aquic Umbriturbels

ABEH. Other Umbriturbels.

Typic Umbriturbels (Ref. #41)

Note: Although there have been few reports of Umbriturbels, they likely occur in maritime areas with dense *Deschampsia* grass, especially on acidic parent materials.

Comments

There have been few reviews of the geography of Antarctic soils particularly in the context of *Soil Taxonomy* (Soil Survey Staff, 1999). In one such review, Beyer et al. (1999) recognized 20 soil subgroups in three regions of Antarctica, King George Island in the South Orkney Group, Casey Station in East Antarctica, and the McMurdo Sound region.

This analysis recognizes 38 subgroups out of a total of 115 subgroups delineated in the Gelisol order (Soil Survey Staff, 1999). Of these subgroups, five occur in the Histel suborder. Histels occur primarily in bedrock depressions in maritime Antarctica, as most of the Histels are in lithic subgroups where bedrock must be within 100 cm of the soil surface. The remaining subgroups were nearly equally divided into the Turbel suborder (17 subgroups) and the Orthel suborder (16 subgroups).

Four new subgroups are proposed herein. Nitric and salic horizons in soils of Pliocene age may be cemented or indurated into petronitric and petrosalic horizons in Anhyorthels and Anhyturbels. Although Petronitric and Petrosalic Anhyturbels do not feature modern cryoturbation, they have relict cryoturbation in the form of sand-wedge casts (Bockheim, 2002).

The Antarctic Permafrost and Soils (ANTPAS) group (http://www.antpas.org/) is preparing maps of eight ice-free regions of Antarctica. The current soil map legend includes only the 42 soil subgroups listed in Table 1. Persons identifying additional soil subgroups are requested to forward soil descriptions, analytical data and any other information to Dr. Megan Balks (m.balks@waikato.ac.nz).

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