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Revised proposed classification for human modified soils in Canada: Anthroposolic order

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Abstract

As the global human population and associated anthropogenic activities rapidly increase, so does the areal extent of disturbed soils. Regulatory frameworks must incorporate reclamation criteria and management options for these disturbed soils, requiring consistent descriptions and interpretations. Many human-altered soils cannot be classified using the current Canadian System of Soil Classification (CSSC), thus an Anthroposolic order is proposed. Anthroposols are soils that are highly modified or constructed by human activity, with one or more natural horizons removed and replaced, added to, or significantly modified. Disturbed horizons are anthropic in origin and contain materials significantly modified physically and/or chemically by human activities. Three great groups are defined by the presence of anthropogenic artefacts and organic carbon content. Eight subgroups are based on the amount of organic material, thickness of horizons, material composition, hydrologic regime, and presence of permafrost. Traditional phases and modifiers are used as in the CSSC. The proposed classification has been revised from the original publication in 2012 after field testing and discussion among soil scientists across Canada. This revised classification is proposed for inclusion in the revised CSSC, to account for the very large and expanding aerial extent of disturbed soils in Canada, and to remain current with other global soil taxonomy systems.

Key words: anthropogenic soil, soil classification, human-made soil, reconstructed soil, reclaimed soil, anthropic soil

Background

Anthroposol definition

Anthroposols are soils that have been highly modified, transformed, or constructed by humans. The name anthroposol is derived from the term "anthropogenic", which originates from the Greek word *anthropos* (man) and the Greek suffix *genes* (caused). Anthroposols are commonly constructed during land reclamation activities to meet regulatory requirements after large and intense anthropogenic disturbances such as mining, land levelling for agricultural operations such as vineyards, or landscaping for urban construction. They may also arise with less deliberate soil construction, such as on landfill sites where the primary goals are burying waste, minimizing leaching, and capping. Anthroposols are common in renewable resources, industrial, commercial, and urban development scenarios, and in transportation, fuel, and power corridors. Anthropogenic soils have various names in different global jurisdictions, including Technisols, Anthrosols, and human-altered and human-transported soils.

The term anthro-pedogenesis has been used to indicate that humans have substantially modified or transformed physical, chemical, and/or biological properties and processes of the soil and transforms our thinking about soil as a natural body to that of a human-natural body (Richter and Yaalon 2012). Soil is in a relatively steady-state after long-term effects of soil-forming factors when humans change its processes and properties via anthro-pedogenesis. The properties of the new soil will thus depend on initial soil properties, intensity of anthro-pedogenetic processes, and resistance and resilience of the initial soil. Most soil scientists associate Dokuchaev and/or Jenny with the model of natural soil formation. The first known reference to anthropogenic soils occurred in 1847 when Ferdinand Senft used the term "anthropogenic urban soils" to describe soils in urban,

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industrial, and mining environments with little fertility due to deposited toxic wastes (Lehmann and Stahr 2007). As we learn more about how soils continue to be substantially influenced by humans, a natural and human co-genesis framework seems more acceptable, similar to defining our current geological epoch as the Anthropocene due to profound human impacts on the global environment since the industrial revolution (Crutzen and Steffen 2003).

Anthroposolic order rationale

The general purpose of any soil classification system is to organize soils so they may be communicated and recalled systematically (Soil Classification Working Group 1998). Although Anthroposols are now common soils, they do not fit into any order in the current Canadian System of Soil Classification (CSSC). Thus their inclusion in CSSC is critical.

The current CSSC uses the p suffix to designate an A or O horizon that has been "disturbed by man's activities such as cultivation, logging, and habitation" (Soil Classification Working Group 1998). Agriculturally tilled soils may be disturbed to varying depths. Since this disturbance generally does not modify the soil profile significantly, such agricultural soils are still classified as being a product of their original soil-forming factors (climate, organisms, relief, parent material, time). A defining feature of the proposed Anthroposolic order is significant human disruption of these soil-forming factors and may include introduction of non-soil materials, and potentially new pedogenic trajectories.

Anthroposols can occur on agricultural landscapes if the disturbance goes beyond typical tillage that can be accounted for with the p suffix in the CSSC. For example, Anthroposols may occur when there is a significant amount of levelling that alters natural soil profiles through excavation and burial, such as during preparation for flood irrigation or land levelling in vineyards and for irrigated potato production. Atlantic Region dike land soils may be considered Anthroposols; dikes exclude seawater from the environment, the landscape has been completely re-shaped with bulldozers and excavators, and deep ditches have been dug for drainage. When a pipeline or well site is constructed in an agricultural field, there may be admixing, to the extent that the soil may be considered as an Anthroposol.

Anthroposolic soils are commonly formed or developed with anthropogenic materials such as peat-mineral mixes, organic-mineral mixes, mine spoil, and phosphogypsum. Composition and arrangement of the layers within an Anthroposol soil profile are the result of human activity. Thus, the dominant soil-forming processes are anthropogenically modified. These factors preclude these modified or reconstructed soils from classification in the existing CSSC. These soils cannot be classified to an existing order, since the current CSSC is pertinent only for soils that have been forming under natural conditions. The most likely trajectory soil development could take, and its eventual equilibrium state is unknown, so they cannot be classified according to what they might evolve to.

To be classified as an Anthroposol, the soil disturbance or modification needs to be evident. In Anthroposols, diagnostic horizons of other CSSC, soil orders may or may not be present in the profile; the Anthroposolic disturbed layer may have been scraped and replaced, materials may be foreign (e.g., phosphogypsum amendment layer), and/or layers may not resemble previous soil horizons (e.g., severely admixed horizons). If the soil was so minimally disturbed (retains its original pedomorphic properties) that it could not be distinguished from its original soil order, it should remain classified in that original soil order. If an anthropogenically modified soil evolves and develops pedogenically to reach conditions diagnostic of one of the existing soil orders in CSSC then the soil could be re-classified at that time.

With increasing anthropogenic activity related to resource, industrial, and urban development, the areal extent of disturbed soils has increased dramatically and continues to increase. Management and land use planning have escalated as disturbed soils are required to meet growing population demands. Regulatory frameworks must incorporate soil reclamation criteria and goals. To meet these needs and apply these regulatory criteria, consistent descriptions and interpretations of these human-altered soils are necessary. Thus, these soils can no longer remain unclassified and the proposed Anthroposolic order is required.

Approaches to anthroposol development

The derivation of an Anthroposolic order within the CSSC began with an examination of definitions of human-altered soils, and an assessment of whether current classification systems and proposed or accepted classification systems of other nations could readily accommodate these soils. No existing system was readily adaptable to anthropogenic soils of Canada, although a number of them influenced development of the proposed Anthroposolic order in the CSSC.

International bases for classification of anthropogenic soils include degree of alteration, presence of artefacts, and soil modifying processes. Numerous attempts in other countries to use current soil taxonomic systems for anthropogenic soils have been documented and usually led to proposals for changes to current systems. Even when human-modified soils seemed to fit into current soil classification systems, qualifiers were raised and degree of fit was low.

Challenges using natural classification systems for anthropogenic soils

Classification of mine soils using the United States Department of Agriculture's taxonomic system, Soil Taxonomy (USDA system) (Soil Survey Staff 1975, 1999; International Union of Soil Sciences 2007), led to many of the earliest classification difficulties and recommendations for different classifications. Ciolkosz et al. (1985) found classifying 24 non-topsoiled, non-cultivated, 1–29 year old Pennsylvania mine soils was most challenging due to weakly expressed cambic

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horizons. They classified 79% of the soils as Entisols and the remaining 21% as Inceptisols. Buondonno et al. (1998) found soils at a dismantled iron and steel plant in Italy that accrued material deposition for over 80 years were so morphologically and chemically different from natural soils that they could not be classified. Thus they proposed a new Foundric subgroup within the Xerorthents.

Meuser and Blume (2001) classified some soils affected by the coal and steel industry in Germany as Plaggic and Hortic Anthrosols, but could not classify soils of anthropo-geomorphic material. These soils did not readily fit the classification systems of the Food and Agriculture Organization of the United Nations, World Reference Base for Soil Resources, and German Soil Science Society Classification systems, so they recommended these systems be improved. Using a USDA soil series, Haering et al. (2005) described particle class, texture, and pH of Virginia mine soils, but unique combinations of drainage class, rock type, colour, and parent materials were far outside the range of the soil series. They initially used spot symbols or map unit inclusions, but proposed a new series when areal extent of the soils increased to several hundred hectares.

Sencindiver and Ammons (2000) discussed continuing classification efforts for anthropogenic soils in the USA. Although series criteria have been formally established, the general consensus among pedologists who have studied mine soils is that current classes do not recognize key features of mine soils and do not convey important information about their management (Anderson 1977; Sencindiver 1977; Schafer 1979; Short et al. 1986; Indorante et al. 1992; Strain and Evans 1994). Ammons and Sencindiver (1990) concluded that mine soil properties were unique and did not always fit established categories of soil taxonomy; thus they proposed a new classification to the family level in the USDA system. Sencindiver (1977) and colleagues (Sencindiver et al. 1978; Thurman et al. 1985; Thurman and Sencindiver 1986; Ammons and Sencindiver 1990) proposed a new suborder Spolents, for mine soils they studied primarily in West Virginia, but included other eastern and mid-western states. They also proposed nine subgroups of Udispolents, which were not adopted.

Fanning and Fanning (1989) proposed revisions to the definition of Typic Udorthents. They also proposed new subgroups for scraped land surfaces (Scalpic), locally derived fill materials moved by earth moving equipment with few or no manufactured inorganic artefacts (Spolic), miscellaneous urban fill materials that contain inorganic manufactured artefacts (Urbic), and organic wastes of human activity (Garbic). Strain and Evans (1994) used the diagnostic criteria established by Fanning and Fanning (1989) for spolic, urbic, or garbic materials or scraped land surfaces for sand and gravel pit soils and proposed Anthrosols as a new order in Soil Taxonomy. The Anthrosols concept was originally proposed by Kosse (1998), but was expanded by Strain and Evans (1994). Suborders of Garbans, Urbans, Spolans, and Scalpans were suggested. Kosse (2001) also proposed distinguishing between anthropogenesis and anthropo-geomorphology and addition of Noosols to the World Reference Base for Soil Resources. Most of these proposed changes were not adopted.

In Germany, Zikeli et al. (2005) tried to classify lignite ash substrate and natural volcanic soil using the World Reference Base. Their young Anthrosols were dominated by lithogenic (parent material) properties, not properties resulting from pedogenic processes. They recommended the World Reference Base include technogenic materials in anthropo-geomorphic soil materials. They proposed a subunit of Technogenic Anthrosols to the German system, suggested recognition of other characteristics and properties at the third and fourth levels of classification according to the group of related natural soils, and included information about important soil constituents such as coal and gypsum, texture, type of deposition, and type of material.

Bryant and Galbraith (2002) suggested not including all anthropogenic soil processes in current classification systems since they do not leave morphological evidence. They found evidence of anthropogenic activity was often expressed in lack of horizonation, altered chemistry or differences in landform relative to surrounding parent materials. Lehmann (2006) presented a similar argument for urban soils strongly influenced by human activities such as construction, transportation, manufacturing processes, industry, mining, and rural housing. He indicated these soils were young and may show weak signs of soil genesis, but were more often identified by easily differentiable substrate-linked features. Since early soil genesis will likely to be influenced by these substrate features, he thought taxonomic differentiation should be based on substrate-linked properties. Hartman et al. (2004) recommended combining useable parts from various proposed disturbed soil taxonomy systems and discussed the implications of a new system after no single taxonomic system seemed to be sufficient to describe two anthropogenic soil profiles.

Toth et al. (2008) discuss Plaggic and Terric Anthrosols of the European Union that occur predominantly around Belgium, the Netherlands, and north-west Germany. Plaggic Anthrosols have the characteristic plaggic horizon produced by long-term addition of animal bedding material, a mixture of organic manure and earth, with fragments of brick and pottery and/or high levels of extractable phosphorus. Formation of most plaggic horizons started in medieval times, leading to horizons more than 1 m thick. Different varieties of Anthrosols are also known as Plaggen soils, Paddy soils, Oasis soils, and Terra Preta do Indio.

Current classification systems for anthropogenic soils

Since 1995, France has included Anthroposols as a major group at the subclass level (Baize and Girard 1998; Lehmann and Stahr 2007). Transformed Anthroposols are soils profoundly altered by agricultural use, usually to improve fertility. Artificial Anthroposols result from inputs of non-pedological materials such as overburden and industrial

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sludges. Reconstituted Anthroposols derive from transported and/or overhauled topsoil. Constructed Anthroposols result from human action to build a soil using technical materials such as waste. Archaeological Anthroposols have undergone ancient anthropic modifications over >50 cm with >20% debris from human activities.

The German soil classification system focuses on anthropogenic urban soils at the soil class level and mainly avoids soil classification terms characterized by substrate properties (Finnern 1994; Sponagel 2005; Lehmann and Stahr 2007). An example is Pararendzina from excavated soil material with rubble, which describes a typical urban soil with lime throughout the profile (Lehmann and Stahr 2007). In Germany, soils of anthropogenic deposits (natural sediments, natural soil substrates, technogenic substrates) result from anthropogenic lithogenesis (Blume and Giani 2005). These anthropogenic deposits are not classified as soils but as human-made parent substrate. They are further classified in the same way as soils of natural substrates. For example, the soil class Reduktosole comprises the soil type Reduktosol, a soil showing signs of reduction by methane. Such soils develop mainly in household waste or in other materials with a high content of young and less decomposed organic matter (Lehmann and Stahr 2007).

The Morphogenetic Soil Classification System of Slovakia includes an anthropogenic soils group with Kultizems (cultivated soils) and Anthrozems (human-made soils) (Collective 2000; Sobocka 2000; Sobocka et al. 2000). The differentiating criterion for Anthrozems is >35 cm of transported (removed) materials called anthropogenic materials. There are Natural, Natural Technogenic, and Technogenic subgroups of Anthrozems. The diagnostic Ad horizon is characterized by a thickness >1 cm, organic carbon content >0.3%, and (or) presence of artefacts (brick, pottery fragments, glass, plastic, iron, slag, coal). The system includes the contaminated Ax horizon for soils affected by exceeded concentrations of toxic or emission elements or compounds. A recent update to the system included considerably more detail on anthropogenic soils (Demko et al. 2018).

The Russian system classifies anthropogenic soils according to degree of naturalness or alteration due to anthropogenic activity with three groups: managed, semi-natural, and natural (Stolbovoi 2002). Managed soils have soil-forming processes guided by humans to meet land use objectives, resulting in human-made soil layers, such as a ploughed layer. Semi-natural soils have characteristics of a naturally formed horizon sequence but reflect some human influences, such as a chalk layer in a topsoil horizon. Natural soils developed under natural soil forming conditions and show no evidence of anthropogenic alteration. This is consistent with the three soil classes of naturally developed, anthropogenically modified, and technogenically disturbed soils used to classify Azerbaijani transformed soils (Babaev et al. 2006). A more detailed approach from an urban soil classification view has been to divide urban soils into open, unsealed areas (Urbanozems), and areas sealed by road surfaces (Ekranozems) (Strogonova and Prokofieva 2002). Within Urbanozems are natural, human-transformed (surface or deep), and human-made soils. Ekranozems can occur on or over any of the Urbanozem classes.

The presence of artefacts in the soil and/or an indication that the soil has been modified by human activity is a key criterion for identification of the great group of Anthroposols, which have been included in the Australian system since as early as 2007 (Isbell and the National Committee on Soil and Terrain 2021). Anthroposols result from human activities leading to a profound modification, mixing, truncation, or burial of their original soil horizon, and creation of new soil parent material. They do not include soils modified by agricultural practices or those systematically drained or flooded. The Australian system has Fusic, Cumulic, Hortic, Garbic, Urbic, Dredgic, Spolic, and Scalpic suborders based on composition of the material and the process through which the material was deposited.

New Zealand Anthropic soils are those disturbed by people through stripping or mixing of the original soil to depth, or through addition of fill including refuse and spoil (Landcare Research 2022). Most of these soils were formed by gold dredging and urban development. The soil order is divided into four groups. Truncated Anthropic soils have most of the pre-existing soil profile removed. Refuse Anthropic soils have waste material that contains significant organic material. Mixed Anthropic soils have drastic disturbance and loss of original character by mixing. Fill Anthropic soils have waste material dominated by inorganic material

In the United Kingdom, classification of artificial (human-made) ground and natural superficial deposits is applied to geological maps and data-sets for extraction of thematic material comprising identified classes of superficial deposits (McMillan and Powell 1999; Rosenbaum et al. 2003). Artificial ground is divided into five classes: made, worked, infilled, landscaped, and disturbed. Made ground is deposited by humans on the former, natural ground surface. Worked ground has been cut away by humans. Infilled ground has been cut away and then had artificial ground (fill) deposited. Landscaped ground has been extensively re-modelled, but it is impractical or impossible to separately delineate areas of made ground and worked ground. Disturbed ground occurs where surface and near-surface mineral workings are ill-defined excavations where areas of human-induced subsidence caused by the workings and spoil are completely associated with each other. Soil groups and soil under groups are further defined (Hollis 1991).

The World Reference Base classification system distinguishes degree of soil alteration and presence of artefacts to define Anthrosol and Technosol groups (International Union of Soil Sciences 2007). Anthrosols have been subjected to intensive agricultural use for some time, while Technosols contain artefacts or technic hard rock (a consolidated product of an industrial process) and can often be toxic. Technosols include soils from wastes such as landfills or mine spoils, pavements and underlying materials, soils with geomembranes, and constructed soils in human-made materials (Nachtergaele 2005; International Union of Soil Sciences 2007; Food and Agriculture Organization of the United

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Nations 2015). In an early review of Technosols, the tradition of splitting organic and mineral soils at the highest level while still recognizing technical origin of these soils was emphasized (Rossiter 2007). Technosols are keyed out as the third Reference Soil Group, after Histosols (soils dominated by organic matter) and Anthrosols (cultivated soils profoundly influenced by long-term human activity).

Refining classification of anthropogenic soils

As new classification systems are applied, the variability in human-influenced soils becomes apparent. What to take into consideration when revising current classification systems or developing new ones is highly debated among soil taxonomists (Ahrens and Engel 1999; Kimble et al. 1999; Burghardt and Dornauf 2000; Sencindiver and Ammons 2000; Wilding and Ahrens 2002; Tejedor et al. 2009).

Burghardt (1994) suggested that when classifying soils in urban and industrial areas, the role of soils in urban ecosystems, effect of change of urban landscape, influence of uses on soils, specific demands in urban areas and their fulfilment by soils, and required and available potentials of soils must be considered. Therefore, characteristics, genesis, and degree of contamination of soils should be known. Blume and Sukopp (1976) differentiated Euhemerob (sites such as arable land and lawn), Polyhemerob (deposits of organic wastes, spolic material, or urban rubble), and Metahemerob (contain toxic materials or are sealed) soils in urban areas. Reinirkens (1988) differentiated soils of buildings, traffic, and recreation sites.

Yaalon and Yaron (1966) suggested a systematic framework for human-made soil changes and named human-induced processes and changes in the soil profile meta-pedogenesis. They suggested a meta-pedogenetic system concept provides a suitable framework so all relevant factors can be marshalled, and the system can serve as a basis for prediction of expected soil changes. They suggested behaviour of a meta-pedogenetic system (resulting soil) depends on intensity of the particular topographical, hydrological, chemical, or cultivation factor and on capacity for adjustment within the initial soil. Diagnostic horizons are not always clearly defined and are certainly not universal. For example, a geomiscic horizon of the World Reference Base Anthrosols describes a horizon that develops when a layer, at least 30 cm thick, of different kinds of earthy materials, is added to the soil using earth moving equipment (Dazzi et al. 2009). The urbic diagnostic horizon being considered in the Russian system is defined as a surface organo-mineral horizon resulting from mixing, filling, burial, or pollution (Stroganova and Prokofieva 2002).

The International Committee on Anthropogenic Soils (ICOMANTH) has been working on a system to classify anthropogenic soils since 1995 (ICOMANTH 2022). They focus on soils derived from human activities that have major alterations; soils that have been so transformed by anthropedogenic processes that the original soil is no longer present or recognizable or survives only as a buried soil. They compare existing classification systems for anthropogenic soils but continue to work on a definitive international approach and terms. In light of the variable soil classification systems currently in existence around the world, it is unlikely that a universal classification for anthropogenic soils will be forthcoming, as each must meld with the non-anthropogenic soil classification system within its jurisdiction. Our proposed system may eventually be used as another section in this collection.

Existing international classification systems cannot be effectively used to address land reclamation and other disturbed soil scenarios common in Canada. These classifications combine material composition and activities. To describe Anthroposols within Canadian settings, we defined great groups on the basis of composition of the material and recognized activities at lower levels within the classification system. Thus, we propose an anthropogenic soils classification for Canada that uses the systematic framework of the CSSC and aims to facilitate the description and management of human-altered soils by soil scientists, soil managers, and industry personnel. Attempts were made to use terms and suffixes that are consistent with their meaning and connotation in the CSSC.

Since the original CJSS 2012 publication

The Naeth et al. (2012) publication proposing an Anthroposol classification for CSSC has been cited numerous times; over 32 times in peer-reviewed publications. Many of these citations are from various parts of Canada including Nunavik and also include China, Russia (including Siberia), Chile, and the United Kingdom. Of particular interest is their use in classifications of various soils in Croatia and urban Russia. The paper is also cited in several books on green technologies, sustainability and urbanization, and in Wikipedia.

There continues to be an increased focus on anthropogenic soils. Capra et al. (2015) provide an interesting and historical review of anthropogenic soils from 64 countries. They suggest that at least 15 classification systems worldwide consider anthropogenic soils at some taxonomic level and credit England and Wales with the first national taxonomic system to include anthropogenic soils and China with the first-order level assignment. They show continued increases in interest in classifying these soils, reflecting the impacts of humans on the pedosphere in the Anthropocene. Several publications have focused on created urban soils, addressed by Guilland et al. (2018).

Numerous researchers have classified the soils in their research papers as Anthroposols, or similar terms. These papers have been published in over 40 different peer-reviewed journals, including those with agriculture, biogeoscience, contaminant remediation, ecology, engineering, environmental, evolution, geochemical, geology, land reclamation, microbiota, micromorphology, pedogenesis, plant science, resource management, soil development, soil genesis, soil science, and sustainability foci. Anthropogenic soils have been featured in books on hydro-informatics,

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pedometrics, sustainable development, urbanization, and urban soils, and in numerous theses and conference proceedings.

Many more countries are proposing inclusion of anthropogenic soils in their classification systems. For example, Husnjak and Spoljar (2019) proposed a method of soil classification for urban, industrial, and military areas in Croatia. They used existing soil survey data from urban areas and industrial and military complexes to determine their properties and suggested classifying the soils as natural, anthropogenic, technological, or technical anthropogenic. The considered anthropogenic soils were ameliorated natural soils for the purpose of agricultural production. Technological and technical soils were newly formed soils solely due to intensive human activity outside of agriculture. They would be in the order of terrestrial soils and in the classes of technogenic or technical soils. In the technogenic soils class, they proposed including two new soil types in addition to landfill and flotation materials, soils of industrial complexes and of military complexes. Five new soil types were proposed for inclusion in the technical soils class, from parks, playgrounds, recreation zones, residential environments, and traffic environments. They provided detailed and clear criteria for separation into lower pedo-systematic units.

Countries already with anthropogenic soils included in their classification systems are embarking on major mapping projects. For example, Gerasimova et al. (2020) are updating the soil map of the Russian Federation, with the Moscow region being used as a model object for testing the new Russian soil classification system, where much attention is paid to soils changed by human activities.

Galbraith and Shaw (2022) developed a practical guide for soil scientists conducting or interpreting a soil survey that includes human-altered and human-transported soils and materials. They discuss how soil survey work in urban areas has progressed over 50 years in the way these soils are described, classified, and mapped. They discuss constructional and destructional anthropogenic landforms and microfeatures now listed in various keys to soil taxonomy and field books for describing and sampling soils.

Key decision pathways

Anthroposols were originally conceptualized (Naeth et al. 2012) as soils that were highly modified or constructed by human activity, with the disturbance visibly evident, occurring ≥10 cm above or below the surface. As we worked on this revision, there were numerous topics that sparked great debate and deep thought. We include the rationale for key decisions made during this revision that were based on extensive discussion with soil scientists from across Canada.

D horizon

The diagnostic D horizons for Anthroposolic soils have organic (>17% organic carbon) or mineral (≤17% organic carbon) soil material of anthropogenic origin. The minimum cumulative thickness of D horizons was increased from 10 to 30 cm from the original proposal (Naeth et al. 2012) and extends to the depth of disturbance, which may be several metres. However, for classification purposes, the control section is considered to be 0–100 cm. In reclaimed soils, the D horizons typically extend from the surface to >100 cm in drastically disturbed lands such as mines and to 30 cm or more in lesser disturbed lands such as pipelines, well sites, and urban areas. Before establishing these depths, various options were considered for minimum thickness, such as depth of cultivation in agricultural fields, depth of original A horizons, and depth of disturbance by construction activities.

Great groups

The Carbic great group denotes soils that resemble original organic soils and have 30 cm or more material with >17% organic carbon in the upper profile. The Spolic great group denotes mineral soils with physical and chemical composition similar to that of the original soils. Both Carbic and Spolic great groups may have artefacts comprising <15% by volume of the horizon. This limit corresponds to the upper limit of the very stony phase of natural soils (Soil Classification Working Group 1998, p. 50), indicating a handicap to cultivation but not preventing it. Defining the technic great group was challenging. This great group may be comprised of mineral and/or organic materials, with a minimum 30 cm cumulative horizons with >15% artefacts. There are many types of physical artefacts (concrete, lumber, metal, etc.) and chemical constituents (hydrocarbons, toxins, etc.) that could comprise a significant portion of the control section, thereby affecting soil characteristics. Knowing the nature and properties of artefacts can be important in understanding soils and in developing appropriate plans and strategies for land management and reclamation. Rather than creating a number of great groups to capture the differences among types of artefacts and chemicals, we grouped them as one. Initially, a cumulative volume ≥10% in a layer ≥30 cm in thickness was assigned to physical artefacts; however, it was changed to ≥15% volume for alignment with classification of native exceedingly stony soils in the CSSC (Soil Classification Working Group 1998).

We considered classifying based on whether chemical constituents were at levels exceeding Canadian environmentally safe thresholds. In the original paper by Naeth et al. (2012), petroleum hydrocarbons and contaminants were recognized as hydrocarbic and contaminic phases, respectively. Hydrocarbic denoted a mineral soil with a horizon containing petroleum hydrocarbons; contaminic denoted a mineral soil containing contaminants such as industrial chemicals, pesticides, wood preservatives, and radionuclides. Since phases are no longer used in the current approach, these materials were tentatively elevated to the great group level because presence of such compounds is considered to be a very important quality of these soils, similar to the use of chemical parameters, such as pH, salinity, and extractable iron and aluminium concentrations in other orders to define subgroups.

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We eventually dropped this focus in the technic great group for several reasons. Concentration is not physically observable, therefore hindering classification being completed in the field. Testing to unknown invisible contaminants would be required every time, and we would have to define a list of contaminants to be tested, significantly increasing costs to the classification process and potentially deterring people from using this system. Contamination could be from non-human causes (salinity, arsenic, boron, tar balls), and we would need to consider background levels for various regions. Since organic carbon could originate from hydrocarbons, wooden artefacts, peat, and/or humus, defining the source would be problematic. This approach would require decisions on which manual we would use for critical defined level, and incorporation of any new editions of that manual. Application of a suffix to minor amounts of contaminants would result in inconsistent use of suffixes. Hence we moved much of this focus to descriptors. Descriptors are terms used to describe or identify important physical or chemical soil properties not recognized at the taxonomic level.

Subgroups

In reviewing the original paper (Naeth et al. 2012), each subgroup was critically examined and modified if necessary or even deleted.

- Egeo was considered a surface layer <10 cm thick, regardless of organic carbon content, over disturbed material. The horizon thickness (<10 cm) was debated; whether 0 cm was acceptable or should be >1 cm or more. We left it as in the original to reflect that for Orthic Regosols, which have an A horizon <10 cm thick and may have a B horizon <5 cm thick.
- Spolo denoted a disturbed soil with a minimum thickness of 10 cm; when the minimum thickness of diagnostic D horizons was increased from 10 to 30 cm, this subgroup became unnecessary.
- Aquo subgroup denotes evidence of prolonged wetness in the soil profile. In the original paper, this subgroup included soils with imperfect, poor, or very poor drainage. Upon deliberation, imperfectly drained soils were included with upland soils as it would be very difficult to identify and describe imperfectly drained conditions (equivalent to gleyed natural soils) given the absence of redox features developed in the new setting. Poorly and very poorly drained soils would have evidence or existence of ponding or shallow water tables.
- Cryo denotes soils that contain diagnostic D horizons and permafrost within 100 cm. This subgroup was examined from the perspective of whether permafrost was an overriding feature, and if so the soils should be considered Anthropic Cryosols. A definition for anthropic, which would denote anthropogenic materials would be needed within the Cryosolic order to distinguish these soils from the current natural great groups and subgroups. Reclaimed soils would develop permafrost over time, thereby qualifying for the Cryosolic order, unless there was unusual chemical composition creating internal warming. Permafrost would be below the root zone and thus growing conditions for vegetation would be governed by the D horizons of the reclaimed soil. Considering the latter, coupled with a desire to maintain all anthropogrenic soils within the Anthroposolic order, the Cryo subgroup was retained.

Labelling topsoils and subsoils

Several scenarios were discussed regarding horizon labelling. For mineral soils, A was initially used to label the surface horizon and D was used for subsurface horizons; this worked well in agricultural soils, while O was applied to organic soil materials (>17% organic carbon). Once suffixes were added, difficulties emerged. Ap was suitable for anthropogenic surface materials derived from original surface horizons (e.g., Ah, Ae, Ap), but Ap did not seem suitable for manufactured surface horizons comprised of peat-mineral mixes, or mineral materials with human-made organic additives, as these horizons would be very different from any conventional Ap. Thus we use Dp for these.

We needed to define the boundary between Ap and some Dp horizons to consistently apply it during field observations. We decided that all surface mineral horizons would be labelled as Dp, D designating anthropogenic material and p designating the surface horizon.

For surface use, we discussed Op or Dop and for subsurface use O1, O2, etc., or Do1, Do2, etc. for organic horizons. Trying to distinguish horizons comprised of natural organic materials (peat) versus those with human-made organic materials (compost, sawdust, etc.) could be difficult in mineral soils. The simplest pragmatic solution appeared to be using Dop for all organic surface horizons. The same issues continue into the subsurface; hence, Do1, Do2, etc. nomenclature was selected for these horizons.

Minimum horizon thickness for subgroups

In many of the natural soil subgroups in the current CSSC, 10 cm is used as the minimum A horizon thickness. In land reclamation scenarios where there is a slight disturbance (well sites, pipelines), topsoil salvage and replacement is typically based on thickness of the A horizon and is normally 10 cm or more. In mining settings, surface soil or cover soil placement is usually 20–30 cm. Rather than assigning different minimum thicknesses for different land reclamation practices which a pedologist mapping the Anthroposolic soils would not necessarily know, we decided to use a 10 cm minimum for all cases.

Suffixes rationale

In revising the proposed Anthroposolic order, it was necessary to add one suffix used in the description of

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non-anthropogenic soils that was not used in the Neath et al. (2012) proposal. The z indicates a perennially frozen layer in the Cryo subgroup.

Degree of disturbance for anthroposols

We considered splitting the Anthroposolic soils as defined in this paper into two broad categories. The Anthropic subgroups of existing natural soil orders would be those resembling natural subgroups but with one or more horizons displaying weak anthropogenic features. The Anthroposolic soils would be those with horizons that are drastically disturbed and not recognizable as original soil horizons. Anthropic soils would have slight modifications, such as admixing, change in macrostructure, differing thickness, and modified horizon boundaries. The main horizons would look very similar to the natural undisturbed horizons; these would occur where natural soils have been disturbed by removing and replacing topsoil and possibly subsoil, as in pipeline and power line corridors and well sites. Existing soil horizon designations (A, B, C) and suffixes would be used in the horizon nomenclature. Anthroposolic soil horizons would contain materials that have been drastically modified physically and/or chemically by human activities. They may consist of materials, such as peat, severely admixed mineral horizons, and/or deeper geological materials; and they may contain non-soil materials such as anthropogenic artefacts (e.g., asphalt, concrete, plastic, geotextiles, rubber, metals, garbage) or manufactured organic wastes (e.g., composts, wood products, fibers, fabrics, jute, hemp). They may also contain petroleum hydrocarbons or toxins. These artificially created layers would be designated as D horizons.

Establishing these two categories would require extensive revisions to many of the subgroups in the existing natural orders and the currently proposed Anthroposolic order would have to be seriously modified to exclude many of the soils presently included. We agreed that making all these changes would be a massive and time-consuming undertaking that would not serve our classification system well in either the short or long term. Therefore, the Anthroposolic order was kept intact.

Anthroposolic order placement in upcoming revised CSSC

Ultimate placement of the Anthroposolic order within the CSSC could depend upon the deemed importance of diagnostic D horizons. In the current soil key, the sequence of orders is based upon the pedogenic importance of each diagnostic horizon. Cryosols are listed first since the presence of permafrost is more important than organics or any other diagnostic horizons of other orders. Similarly, Vertisolic soils having vertic and slickenside horizons are more critical than soils with a Podzolic B horizon and do not have a Bt horizon. If no diagnostic horizons are present for any other soil orders, the Regosolic order is the last resort. Thus, the Anthroposolic order could precede the Cryosolic order indicating that the disturbed upper profile and growing medium is more critical during the growing season than the deeper permafrost.

The supporting reasons for including Anthroposolic soils last are numerous and applicable. Most soils in the Anthroposolic order are derived from existing orders, or they are constructed to be somewhat similar to existing soils; thus it seems logical that they should follow other orders in the taxonomic system. Anthroposolic soils are a new order with much less experience and study by pedologists; thus it is preferred that this order be an added order rather than a leading order. Anthroposolic soils are comparatively minor in extent, and mapping of these soils is just beginning.

In preparing the soil key, it is simplest to have the Anthroposolic order placed first in the upcoming revised CSSC. Basically, if there are more than 30 cm of anthropogenic material in the 0–100 cm control section, the soil belongs to the Anthroposolic order; if there is less than 30 cm of anthropogenic material, then proceed to other orders in accordance with the current key to soil orders (Soil Classification Working Group 1998).

The proposed anthroposolic order

Horizon names used with anthroposols

Anthroposols are soils that have been highly modified or constructed by human activity. The soil disturbance or modification is visibly evident and is ≥30 cm thick within the 0–100 cm control section. One or more natural horizons may be removed then replaced, added to, or significantly modified by human activities. Anthroposols have horizons that are human created and not recognizable as original soil horizons. Manufactured materials of domestic and/or industrial origin may be added as a horizon or a component of a horizon. Anthropogenic artefacts may be imbedded in a matrix. Anthroposols do not include soils that are modified by common agricultural practices, such as cultivation, or by artificial drainage, flood irrigation, and deep tillage.

Disturbed horizons

Anthroposols have disturbed horizons characterized as follows.

D is a horizon identifying organic (>17% organic carbon) or mineral (≤17% organic carbon) soil material of anthropogenic origin. Multiple D horizons may be described in one soil profile, each one recognized on the basis of different chemical or physical properties. The D horizons are diagnostic for Anthroposols. These organic or mineral horizons have been disturbed by anthropogenic activity or constructed from unconsolidated non-soil materials. They are characterized by any or all of the following.

- Composed of transported and separately handled horizons, (e.g., Ap, Bm) or a physical mixture of two or more native horizons (e.g., Bm, BC).

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- Containing any artefacts such as fragments of lumber, concrete, metal, plastic, ceramic, rubber, fabric, or other items recognizable as human made.
- Composed of unconsolidated non-soil materials such as mine waste, including materials containing hydrocarbons, toxins, or industrial processing waste.
- Having recognizable evidence of past excavation (e.g., abrupt differences between materials or horizons within short horizontal distances).
- Any other evidence of anthropogenic disturbance.

The definition of anthropogenic parent materials is the same as for the D horizon. It often includes modification to the geological materials and changes to the landform, as in reclaimed mines.

L, F, and H horizons are only used in Anthroposols when a leaf litter layer has developed naturally from the vegetation on the reclaimed landscape, or a thatch layer develops on the surface under no-tillage conditions (Miller et al. 2022). They are defined the same as for non-anthropogenic soils, for plant litter of various stages of decomposition. L has original structures easily recognizable, F has some original structures difficult to recognize, and H has decomposed organic matter with indiscernible structures. Organic O horizons are only used in Anthroposols when a peat layer <40 cm thick has developed from decaying wetland vegetation.

Suffixes

Four suffixes used in the current CSSC are also used with the D horizons. As Anthroposols develop further with time, other suffixes may be used when the horizon meets the requirements specified in the CSSC.

- Suffix k indicates the presence of carbonate (visible effervescence when dilute hydrochloric acid is applied) in any horizon.
- Suffix p indicates a surface horizon disturbed by human activities such as cultivation, logging, habitation, and reclamation. It may be used as Dp for mineral materials or Dop for organic materials forming the surface horizon. In land reclamation, the Dp or Dop may be a regularly cultivated horizon or it may be a one-time placement of surface soil, also referred to as cover soil or topsoil. It is intended as a primary growing medium for vegetation.
- Suffix s indicates any horizon with salts visible as crystals or veins within the horizons or as a crust at the soil surface.
- Suffix z indicates a perennially frozen layer that may be used with any horizon.

Four new suffixes are proposed to articulate features of anthropogenic soils that cannot be expressed with current suffixes used for non-anthropogenic soils.

- Suffix i indicates the presence of toxins (contaminants) in a soil horizon.
- Suffix o indicates organic materials composed of >17% organic carbon.
- Suffix q indicates occurrence of hydrocarbons in a soil horizon. Since different jurisdictions have different recommended analytical methods and threshold levels for toxins and hydrocarbons, a standard is not proposed; rather the analytical methods and standards used should be referenced in the soils report.
- Suffix w indicates waste materials and/or the presence of artefacts, which are >2 mm in diameter. The w suffix is used when wastes occupy ≥15% (volume) of any horizon. Waste does not include geologic coarse fragments, fractured rock, and coal.

Successive horizons

Numbers are used as suffixes to denote successive D horizons as specified under rules concerning horizon and layer designations in the CSSC.

Roman numeral prefixes are used in anthropogenic soil descriptions to denote a buried original undisturbed horizon; for example, Dp, D, IIBm.

Great groups

Great group rationale

The great group level in the CSSC is "based on properties that reflect differences in the strengths of dominant processes, or a major contribution of a process in addition to the dominant one" (Soil Classification Working Group 1998). In the proposed Anthroposolic order, the dominant process is human influence on the composition, arrangement, and/or replacement of horizons following an intensive human disturbance. Several great group options were considered, including the nature and intensity of the disturbance (such as an intensive mining operation versus simple horizon stripping), the remedial procedure used (such as a reclamation prescription), and the physical and/or chemical composition of the modified soil (such as the use of human-made amendments).

The decision to use the composition of the materials of the horizons of the soil to define great groups was based upon the common scenario where pedologists are working on a landscape, without prior knowledge of the activities that took place, and are required to classify the soil beneath their feet. When basing the great group level on material composition of the horizons, the pedologist does not need a detailed history of the site, which is often not available. The classification is dynamic and could change as the newly formed soil changes with time. The classification will provide insight into potential future uses of the site, management options, and challenges.

Great groups are based on composition of the horizons within the control section. The diagnostic disturbed D horizon of Carbic and Spolic Anthroposol great groups is the one encompassing the uppermost ≥30 cm of organic or mineral material, respectively, (cumulative thickness of Dop, Do1, etc. or Dp, D1, etc.). A Technic Anthroposol has ≥30 cm

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Table 1. Great groups of the proposed Anthroposolic order and their composition.

Horizon composition	Carbic Anthroposol	Spolic Anthroposol	Technic Anthroposol
Anthropogenic artefacts	<15% by volume	<15% by volume	≥15% by volume
Organic carbon	>17% by weight	≤17% by weight	Any
Profile location	Upper	Upper	Any

cumulative D and/or Do horizons with artefacts anywhere within the 100 cm control section.

When a modified profile is <100 cm, a natural soil horizon will exist without modification within the 100 cm control section. The great group description will then apply to the uppermost horizon that occupies at least 50% of the depth of the modified profile, or the greatest cumulative proportion thereof. For example, if the depth of modification is 40 cm, the horizon upon which the great group level of classification applies would be ≥20 cm in thickness.

Great group descriptions

The three great groups proposed are Carbic, Spolic, and Technic (Table 1), each with ≥30 cm of cumulative D horizons. They are defined by the organic carbon content; Carbic >17% or Spolic ≤17% organic carbon by weight, each with <15% artefacts by volume; or Technic with ≥15% artefacts regardless of organic carbon content.

The diagnostic feature of the Carbic great group is the presence of sufficiently deep Do horizons to meet the depth criterion (≥30 cm cumulative horizons within the upper part of the profile that contains >17% organic carbon). This great group may have physical artefacts present; if present they constitute <15% by cumulative volume. The organic material may be of natural or manufactured origin (manufactured organic wastes, composts, sawdust, and/or mulches added as amendments). This great group will usually describe reclamation prescriptions requiring peat or peat-mineral mixes; such as those currently being used in the oil sands areas of Alberta, or forest industry and urban organic materials currently being used in the metal mining and gravel extraction areas of Ontario. Carbic is used to imply organic carbon of a variety of origins. Any horizon within the control section may also contain hydrocarbons and/or toxins which would be noted by a q and/or i horizon suffix, respectively, and as a descriptor. Carbic is from the Latin carbo (carbon).

The diagnostic feature of the Spolic great group is the presence of a sufficiently deep D horizon to meet the depth criterion (≥30 cm within the uppermost part of the 100 cm control section) and containing ≤17% organic carbon. This great group generally does not have artefacts present; if present they constitute <15% by cumulative volume within horizons. The Spolic great group may include buried sumps or materials deposited as a slurry from human processes such as mining (e.g., tailings ponds, waste rock). It may include removed and replaced soil horizons or materials deposited in a horizon from human activities such as dredging. For example, a soil profile with a few shards of glass or a thin horizon of an unnatural amendment (such as drilling mud) would be included within this great group. Hydrocarbons and/or toxins derived from soils and/or overburden materials may be present which would be noted by a q and/or i horizon suffix and as a descriptor. Spolic is derived from the Latin spolio (to strip or denude).

The diagnostic feature of the Technic great group is the presence of a D horizon that is ≥30 cm thick anywhere within the 100 cm control section, containing >15% artefacts (by cumulative volume within one or more horizons). This material justifies the Technic great group name, regardless of the amount of organic carbon. Any horizon within the control section may also contain hydrocarbons and/or toxins which would be noted by a q and/or i horizon suffix, respectively, and as a descriptor. Technic is from the word technical denoting human made or artificial; its origin is the Latin technicus.

Subgroups

Subgroup rationale

As in the CSSC, subgroups are differentiated on “the kind and arrangement of horizons that indicate conformity to the central concept of the group, intergrading towards soils of another order, or additional special features within the control section” (Soil Classification Working Group 1998). Subgroups in the Anthroposolic order are based on profile features within the control section and characteristics of the surface soil horizons. Table 2 shows the sequence for keying the great groups and subgroups.

Subgroup descriptions

Proposed subgroups Terro, Cryo, Aquo, and Modal are based on profile features; and Carbo, Egeo, Albo, and Fusco are based on surface soil features (Table 2). These subgroups reflect the depth of anthropogenic material, presence of permafrost, hydrologic regime, organic carbon content, and thickness of surface horizons as described below.

The Terro subgroup denotes soils with shallow disturbances. The depth of disturbance is less than the depth of the control section as indicated by the presence of at least 1 cm of original undisturbed parent material (organic or mineral) or bedrock within the control section. The word terro in Latin connotes earth, a sense of naturalness.

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Table 2. Summary of Great Group and Subgroup features.

Great groups	Features
Carbic	Presence of Do horizon ≥30 cm thick in upper profile with >17% organic carbon and <15% artefacts in any horizon
Spolic	Presence of D horizon ≥30 cm thick in upper profile with ≤17% organic carbon and <15% artefacts in any horizon
Technic	Soil that is mineral and (or) organic and has a ≥30 cm cumulative layer with ≥15% artefacts (volume basis)
Subgroups	Profile features
Terro	Anthropogenic material is <100 cm deep, overlying natural soil or bedrock
Cryo	Soil has permafrost in the control section
Aquo	Soil has wetland features
Modal	Anthropogenic material ≥100 cm, dryland (very rapidly to imperfectly drained), no permafrost
Subgroups	Surface Soil Features
Carbo	Surface horizon is ≥10–30 cm, ≥17% organic carbon
Egeo	Surface horizon is <10 cm thick, variable organic carbon
Albo	Surface horizon is ≥10 cm, <2% organic carbon
Fusco	Surface horizon is ≥10 cm, 2–17% organic carbon

The Cryo subgroup denotes soils with a diagnostic D horizon and the presence of permafrost. Therefore, Cryo is used as a subgroup to indicate that permafrost has developed within the 100 cm control section regardless of the material and great group. Cryo is from the Greek, kruos, meaning icy cold.

The Aquo subgroup denotes soils with poor or very poor drainage. Evidence of mottles and gleying are not necessarily diagnostic in the anthropogenically disturbed environment as they may be relict features of a transported soil material, or they may not have had time to develop since disturbance. To be classified in the Aquo subgroup, an Anthroposol must have evidence of prolonged wetness in the soil profile, such as a water table or saturated soil in a horizon, and hydrophytic vegetation. These soils normally occur on concave lower slope positions. If there are adjoining natural soils, as along pipelines, those soils are typically Gleysols, indicating the influence of periodic or sustained reducing conditions during their genesis. Aquo is from the Latin aqua, meaning water.

The Modal subgroup does not have any of the features of the Terro, Cryo, or Aquo subgroups, and thus denotes a profile that contains mineral and/or organic horizons with a cumulative thickness ≥100 cm, no permafrost, and dryland conditions (very rapidly to imperfectly drained).

The Carbo subgroup denotes soils with a surface horizon (Dop or Do) that is ≥10 cm thick and has >17% organic carbon. It normally occurs in the Technic and Spolic great groups, but it may also occur in the Carbic great group where there is a distinguishable surface organic horizon (Dop) overlying deeper organic material (Do). Carbo, the same as for the Carbic great group, reflects organic carbon from a variety of sources. Material comprising this horizon may be derived from peat (Of, Om, Oh), or manufactured organic materials such as compost, mulches, and organic wastes. The Carbo subgroup is named from the Latin carbo, meaning carbon.

The Egeo subgroup denotes a surface horizon that is <10 cm thick, regardless of its organic carbon content, over another horizon (D) of disturbed material. If there is no Dp or Dop horizon, the surface horizon is designated a D or Do. The Egeo subgroup is named from the Latin egeo meaning to lack or to be without.

The Albo subgroup denotes soils with a surface horizon (Dp) that is ≥10 cm thick and has <2% organic carbon (determined in the laboratory, although colour may be used as an approximation in the field). This low amount of organic carbon would normally account for its light colour. This may be comprised of a natural Ae that has been placed on a reclaimed surface, sandy material, or ash. The Albo subgroup is named from the Latin albus, meaning white.

The Fusco subgroup denotes soils with a surface horizon (Dp) that is ≥10 cm in thickness and has 2%–17% organic carbon (determined in the laboratory, although colour may be used as an approximation in the field). This higher amount of organic carbon would normally account for its darker colour relative to the Albo subgroup. This horizon may be comprised of material originating from a natural Ap, Ahe, or Ah horizon, a mix of peat and soil, or addition of organic amendments to soil material. The Fusco subgroup is named from the Latin fusc, meaning to make dark.

Phases and descriptors

In the original paper by Naeth et al. (2012), phases were used in the proposed Anthroposolic order, following the subgroup name, to denote specific characteristics of Anthroposolic soils. These included descriptions of chemical and physical properties; for example, calcareous, dystric, and clayic, compactic, respectively. In the current CSSC, it is stated that "a soil phase is a unit of soil outside the system of soil taxonomy". As such, a phase name cannot be added to a taxonomic name. Therefore, at this time we recommend that when mapping soils, important properties not recognized in the taxonomic system be added as descriptors. It is anticipated that there will be many descriptors used initially, but only a portion will gain widespread use. In the future, those widely used could be incorporated into the CSSC.

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Example profiles and classifications

Urban examples

See Tables 3 and 4 for examples.

Modal Fusco Technic Anthroposol

Table 3. Setting: landfill site capped with spolic material.

Horizon	Depth (cm)	Texture	Colour	Comments
Dp	0–20	Loam	10YR 3/2 (d)	5% organic carbon
D	20–30	Clay loam	10YR 5/4 (d)	5% coarse fragments
Dk	30–45	Sandy clay loam	2.5YR 5/2 (d)	15% coarse fragments, moderately calcareous
Dw	45–100	Loam	10YR 2/1 (d)	Organic rich matrix, 20%–30% artefacts of scraps of plastics, metal, lumber

Rationale
- Technic because technic material (≥15% artefacts) is the dominant horizon (Dw) in the control section (>55 cm).
- Fusco because the surface horizon (Dp) is ≥10 cm thick, and organic carbon content is between 2% and 17%.
- Modal because it is ≥100 cm thick, dryland, and has no permafrost.

Terro Fusco Spolic Anthroposol

Table 4. Setting: landscaped residential property.

Horizon	Depth (cm)	Texture	Colour	Comments
Dp	0–15	Loam	10YR 3/4 (m)	Imported topsoil, 5% organic carbon
D	15–60	Loamy sand	5YR 5/6 (m)	Mix of A and B horizon material from sandy glaciofluvial deposit, pH 4.4
IIBC	60–100	Sand	2.5YR 4/4 (m)	Sandy glaciofluvial deposit, pH 4.9

Rationale
- Spolic because the dominant disturbed horizon (D) is ≥30 cm thick, has <15% artefacts, and contains ≤17% organic carbon.
- Fusco because the surface horizon is ≥10 cm and has 2%–17% organic carbon.
- Terro because the anthropogenic material is <100 cm deep, overlying natural soil.

Oil and gas examples

See Tables 5, 6, and 7 for examples.

Terro Fusco Spolic Anthroposol

Table 5. Setting: reclaimed pipeline right-of-way on an Orthic Black Chernozem.

Horizon	Depth (cm)	Texture	Colour	Comments
Dp	0–22	Loam	10YR 3/1 (d)	Organic carbon 6%, replaced original Ap
D	22–45	Clay loam	10YR 5/4 (d)	Mix of original B and BC horizon
IIBC	45–65	Clay loam	10YR 5/3 (d)	Undisturbed natural subsoil
IICk	65–100	Clay loam	10YR 5/2 (d)	Undisturbed natural subsoil

Rationale
- Spolic because dominant material is ≥30 cm thick, has <15% artefacts, and contains ≤17% organic carbon.
- Fusco because the surface horizon is ≥10 cm and has 2%–17% organic carbon.
- Terro because the anthropogenic material is <100 cm deep, overlying natural soil.

Terro Egeo Spolic Anthroposol

Table 6. Setting: well site pad located on a fen, west central Alberta.

Horizon	Depth (cm)	Texture	Colour	Comments
Dp	0–5	Loam	10YR 4/2 (d)	Organic carbon 3%
D1	5–25	Clay	10YR 6/2 (d)	—
D2	25–45	Cobbly	10YR 5/3 (d)	Rip rap with 75% cobles, little matrix material
IIOm	45–100	Peat	10YR 4/2 (d)	Original organic fen (mesic) surface horizon

Rationale
- Spolic because the dominant disturbed material is ≥30 cm thick, has <15% artefacts, and contains ≤17% organic carbon.
- Egeo because the surface Dp horizon is <10 cm thick.
- Terro because the anthropogenic material is <100 cm deep, overlying natural soil (organic fen).

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Modal Fusco Spolic Anthroposol

Table 7. Setting: reclaimed pipeline (three lift), in southern Alberta.

Horizon	Depth (cm)	Texture	Colour	Comments
Dp	0–15	Loam	10YR 3/3 (m)	Organic carbon 3%
D	15–35	Clay loam	10YR 4/3 (m)	Original B and BC horizon material
Dks	35–100	Clay loam	2.5YR 5/3 (m)	Moderately calcareous, EC 6 dS m^{-1}

Rationale
- Spolic because the dominant disturbed material is ≥30 cm thick, has <15% artefacts, and ≤17% organic carbon.
- Fusco because the surface horizon is ≥10 cm and has 2%–17% organic carbon.
- Modal because it is ≥100 cm thick, dryland, and has no permafrost.

Oil sands examples

See Tables 8, 9, and 10 for examples.

Modal Carbo Spolic Anthroposol

Table 8. Setting: reclaimed area in the Athabasca oil sands region, northwest of Fort McMurray, Alberta.

Horizon	Depth (cm)	Texture	Colour	Comments
Dop	0–20	Peat	10YR 2/2 (d)	Mesic peat, organic carbon >17%
Dk1	20–45	Clay loam	10YR 2/2 (d)	Original B and C horizons mix, weakly calcareous
Dk2	45–100	Sand	10YR 5/3 (m)	Tailings sand, weakly calcareous

Rationale
- Spolic because the dominant disturbed material is ≥30 cm thick, has <15% artefacts, and ≤17% organic carbon).
- Carbo because the surface horizon (Dop) is organic material containing ≥17% organic carbon and is ≥10–30 cm thick.
- Modal because it is ≥100 cm thick, dryland, and has no permafrost.

Modal Fusco Spolic Anthroposol

Table 9. Setting: reclaimed area in the Athabasca oil sands region, northwest of Fort McMurray, Alberta.

Horizon	Depth (cm)	Texture	Colour	Comments
Dp	0–20	Loam	10YR 3/2 (d)	Peat mineral mix, 10% organic carbon
Dqk	20–100	Clay loam	10YR 3/1 (d)	Overburden containing lean oil sands, weakly calcareous

Rationale
- Spolic because the dominant disturbed material in the control section has a ≥30 cm cumulative layer with <15% artefacts.
- Fusco because the surface horizon (peat mineral mix) is ≥10 cm thick and has 2%–17% organic carbon.
- Modal because it is ≥100 cm thick, dryland, and has no permafrost.
- Descriptor would note presence of hydrocarbons, concentrations and analytical methods would be provided.

Aquo Fusco Spolic Anthroposol

Table 10. Setting: reclaimed low lying area in the Athabasca oil sands region, northwest of Fort McMurray, Alberta.

Horizon	Depth (cm)	Texture	Colour	Comments
Dp	0–20	Loam	10YR 3/2 (d)	Peat mineral mix, 8% organic carbon, evidence of water ponding on the surface
Dk1	20–50	Clay loam	10YR 4/3 (d)	Mixture of B and C horizon material
Dk2	50–100	Clay loam	10YR 4/2 (m)	B and C material mix, water table at 50 cm

Rationale
- Spolic because the dominant disturbed material is ≥30 cm thick, has <15% artefacts, and ≤17% organic carbon.
- Fusco because the surface horizon (peat mineral mix) is ≥10 cm thick and has 2%–17% organic carbon.
- Aquo because it is low lying and has a water table at 50 cm, evidence of earlier ponding.

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Industrial examples

See Tables 11 and 12 for examples.

Terro Fusco Spolic Anthroposol

Table 11. Setting: old sawmill site, mainland Nova Scotia.

Horizon	Depth (cm)	Texture	Colour	Comments
D1	0–12	Sandy loam	2.5Y 2.5/1 (m)	Compacted mineral soil, wood chips, sawdust mix with 6% organic carbon, 20% coarse fragments, pH 5.2
D2	12–65	Sandy loam	2.5Y 4/3 (m)	B and C material mix with 50% coarse fragments, pH 4.9
R	65	—	—	Slate bedrock

Rationale

- Spolic because the dominant disturbed material (D) is ≥30 cm thick, has <15% artefacts, and ≤17% organic carbon.
- Fusco because the surface horizon is ≥10 cm thick and has 2%–17% organic carbon.
- Terro because the anthropogenic material is <100 cm deep, overlying bedrock.

Modal Egeo Spolic Anthroposol

Table 12. Setting: partially reclaimed surface coal mine site, Cape Breton, Nova Scotia.

Horizon	Depth (cm)	Texture	Colour	Comments
Dp	0–4	Sandy loam	7.5YR 4/2 (m)	Contoured overburden mix with broken Dp horizon associated with patchy graminoid cover
D1	4–45	Sandy loam	7.5YR 5/2 (m)	Contoured overburden mix with relict redoximorphic concentrations (mottles), 20% coarse fragments
D2	45–100	Sandy loam	7.5YR 4/3 (m)	Contoured overburden mix, 30% coarse fragments

Rationale

- Spolic because the dominant horizon (D) is ≥30 cm thick, has <15% artefacts, and ≤17% organic carbon.
- Egeo because the surface horizon is <10 cm.
- Modal because it is ≥100 cm thick, dryland, and has no permafrost.

See Appendix A for actual field classifications and Appendix B for summary keys.

Next steps

Anderson and Smith (2011) present a historical documentation of soil classification and soil survey in Canada; from the first soil surveys in 1914, to the first meeting of the National Soil Survey Committee in 1945, to the first edition of the CSSC in 1978. They outline the 1990s decline of soil survey activities and the following rise as the need for environmental assessments increased. They speak of the "ongoing interest in and need for soil information" and the challenge for pedologists "to provide reliable information in innovative and proactive ways". They include a statement from 1960 that "to reach this goal (of a national taxonomic system) probably everyone concerned had to sacrifice some cherished concept", reminding us that "the classification system may not entirely be satisfactory to the individual soil scientists who are responsible for it, but it does represent the best collective viewpoint on soil classification in Canada at the present time". That quote is relevant today in 2022, prefacing the way for the Anthroposolic order in the CSSC.

The proposed Anthroposolic order has been tested and applied to a considerable number of field scenarios across Canada since the original proposal in 2012. We believe it is ready to be submitted to the Pedology Committee of the Canadian Society of Soil Science to be considered for inclusion in the CSSC revision four. Please contact us (anaeth@ualberta.ca) if you wish to participate in further field trials.

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Data availability

There are not data to deposit.

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Appendix A: Actual classified field sites

Fig. A1. Photo courtesy of Konstantin Dlusskiy.

Table A1. Terro Fusco Spolic Anthroposol, an urban soil in the city of Edmonton, Alberta, Canada, with two layers of placed topsoil and crushed rock over in situ glaciolacustrine clay.

Horizon	Depth (cm)	Colour	Texture	Structure
Dp	0–17	10YR 2/2 (d)	L	W–M–SBK
Dk1	17–45	10YR 3/4 (m)	grSCL	MA
D1	45–72	10YR 3/4 (m)	grSCL	MA
Dk2	72–90	2.5Y 4/3 (m)	CL	MA
IICk	90–100	2.5Y 4/2 (m)	SiC	MA

Great group
• Spolic because the dominant disturbed material in the control section (100 cm of the surface) is spolic (≥30 cm thick, <15% artefacts, and ≤17% organic carbon).
Subgroup
• Fusco because the surface layer (placed soil) is ≥10 cm thick, and organic carbon is 2% and 17%.
• Terro because depth of the disturbance is less than the control section with >10 cm of original parent material (IICsk horizon) within 100 cm depth.

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Fig. A2. Photo courtesy of Konstantin Dlusskiy.

Table A2. Modal Fusco Spolic Anthroposol in a 16 year old reclaimed area in the Athabasca Oil Sands Region of Alberta, Canada, constructed with peat mineral mix on tailings sand.

Horizon	Depth (cm)	Colour	Texture	Structure
LF	3–0	—	—	—
Dp	0–18	10YR 3/4 (d)	fSL	M–M–SBK
D1	18–100	10YR 4/3 (m)	fS	SG

Great group
• Spolic because the dominant disturbed material in the control section (within 100 cm of the surface) is spolic (≥30 cm thick, <15% artefacts, and ≤17% organic carbon).
Subgroup
• Fusco because the surface layer (peat mineral mix) is ≥10 cm thick, and organic carbon is between 2% and 17%.
• Modal because it is ≥100 cm thick, dryland, and has no permafrost.
Note development of the LF horizon and structure in the Dp horizon that indicates the beginning of boreal soil formation.

Fig. A3. Photo courtesy of Graeme Spiers.

Table A3. Modal Fusco Spolic Anthroposol in a 50 year old limed tailings dam near Sudbury, Ontario, Canada, that was planted with conifers.

Horizon	Depth (cm)	Colour	Texture	Structure
LF	7–0	—	—	—
Dp	0–18	10YR 3/4 (d)	fSL	M–M–SBK
D	18–100	10YR 4/3 (m)	fS	SG

Great group
• Spolic because the dominant disturbed material in the control section (within 100 cm of the surface) is spolic (≥30 cm thick, <15% artefacts, and ≤17% organic carbon).
Subgroup
• Fusco because the surface layer (peat mineral mix) is ≥10 cm thick, and organic carbon is between 2% and 17%.
• Modal because it is ≥100 cm thick, dryland and has no permafrost.
Note no obvious decomposition in the humus forms.

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Fig. A4. Photo courtesy of Graeme Spiers.

Table A4. Modal Fusco Spolic Anthroposol in a 5 year old reclaimed site on a low sulphur tailings management area near Onaping Falls, Ontario, Canada, constructed with organic materials, mainly a low grade compost.

Horizon	Depth (cm)	Colour	Texture	Structure
Dp	0–12	10YR 4/2 (m)	fS	M–F–SBK
D1	12–45	10YR 3/4 (m)	fSL	M–M–SBK
D2	45–100	10YR 4/3 (m)	fSL	M–SG

Great Group
- Spolic because the dominant disturbed material in the control section (within 100 cm of the surface) is spolic (≥30 cm thick, <15% artefacts, and ≤17% organic carbon).

Subgroup
- Fusco because the surface layer (urban and forestry mixed source organic material mix) is ≥10 cm thick and organic carbon is between 2% and 17%.
- Modal because it is ≥100 cm thick, dryland, and has no permafrost.

Note that these organic soils were cultivated annually for about 5 years as experimentation was conducted with various crops and fertilizer additions.

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Appendix B: Summary keys

Note that these summary keys are based on conceptualized possibilities for soils, not those that have currently been found on any sites with Anthroposols.

Summary key for Spolic Anthroposols

A. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10–30 cm thick with ≥17% organic carbon and <15% volume artefacts in any horizon …… Terro Carbo Spolic Anthroposol

B. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon <10 cm thick and <15% volume artefacts in any horizon …… Terro Egeo Spolic Anthroposol

C. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10 cm thick with <2% organic carbon and <15% volume artefacts in any horizon …… Terro Albo Spolic Anthroposol

D. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10 cm thick with 2%–17% organic carbon and <15% volume artefacts in any horizon …… Terro Fusco Spolic Anthroposol

E. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and <15% volume artefacts in any horizon …… Terro Cryo Carbo Spolic Anthroposol

F. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon <10 cm thick, and <15% volume artefacts in any horizon ……Terro Cryo Egeo Spolic Anthroposol

G. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10 cm thick with <2% organic carbon, and <15% volume artefacts in any horizon…… Terro Cryo Albo Spolic Anthroposol

H. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10 cm thick with 2%–17% organic carbon, and <15% artefacts volume in any horizon…… Terro Cryo Fusco Spolic Anthroposol

I. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and <15% volume artefacts in any horizon …… Terro Aquo Carbo Spolic Anthroposol

J. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon <10 cm thick, and <15% volume artefacts in any horizon …… Terro Aquo Egeo Spolic Anthroposol

K. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10 cm thick with <2% organic carbon, and <15% volume artefacts in any horizon …… Terro Aquo Albo Spolic Anthroposol

L. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10 cm thick with 2%–17% organic carbon, and <15% volume artefacts in any horizon …… Terro Aquo Fusco Spolic Anthroposol

M. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, with a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and <15% volume artefacts in any horizon…… Terro Cryo Aquo Carbo Spolic Anthroposol

N. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, with a surface horizon <10 cm thick, and <15% volume artefacts in any horizon …… Terro Cryo Aquo Egeo Spolic Anthroposol

O. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, with a surface horizon ≥10 cm thick with <2% organic carbon, and <15% volume artefacts in any horizon …… Terro Cryo Aquo Albo Spolic Anthroposol

P. Spolic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, with a surface horizon ≥10 cm thick with 2%–17% organic carbon, and <15% volume artefacts in any horizon …… Terro Cryo Aquo Fusco Spolic Anthroposol

Q. Spolic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon ≥10–30 cm thick with ≥17% organic carbon and <15% volume artefacts in any horizon …… Modal Carbo Spolic Anthroposol

R. Spolic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon <10 cm thick and <15% volume artefacts in any horizon …… Modal Egeo Spolic Anthroposol

S. Spolic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon ≥10 cm thick with <2% organic carbon and <15% volume artefacts in any horizon…… Modal Albo Spolic Anthroposol

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T. Spolic Anthroposol composed of anthropogenic material is ≥100 cm deep with a surface horizon ≥10 cm in thickness with 2%–17% organic carbon and <15% volume artefacts in any horizon .... Modal Fusco Spolic Anthroposol

Summary key for Carbic Anthroposols

A. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10–30 cm thick with ≥17% organic carbon and <15% volume artefacts in any horizon .... Terro Carbo Carbic Anthroposol
B. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon <10 cm thick and <15% volume artefacts in any horizon .... Terro Egeo Carbic Anthroposol
C. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10 cm thick with <2% organic carbon.. Terro Albo Carbic Anthroposol
D. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10 cm thick with 2%–17% organic carbon .... Terro Fusco Carbic Anthroposol
E. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and <15% volume artefacts in any horizon .... Terro Cryo Carbo Carbic Anthroposol
F. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon <10 cm thick, and <15% volume artefacts in any horizon .... Terro Cryo Egeo Carbic Anthroposol
G. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10 cm thick with <2% organic carbon...................................... Terro Cryo Albo Carbic Anthroposol
H. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10 cm thick with 2%–17% organic carbon................................. Terro Cryo Fusco Carbic Anthroposol
I. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and <15% volume artefacts in any horizon, ... Terro Aquo Carbo Carbic Anthroposol
J. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon <10 cm thick, and <15% volume artefacts in any horizon .... Terro Aquo Egeo Carbic Anthroposol
K. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10 cm thick with <2% organic carbon .... Terro Aquo Albo Carbic Anthroposol
L. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10 cm thick with 2%–17% organic carbon .... Terro Aquo Fusco Carbic Anthroposol
M. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, with a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and <15% volume artefacts in any horizon .... Terro Cryo Aquo Carbo Carbic Anthroposol
N. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, with a surface horizon <10 cm thick, and <15% volume artefacts in any horizon .... Terro Cryo Aquo Egeo Carbic Anthroposol
O. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, a surface horizon ≥10 cm thick with <2% organic carbon .... Terro Cryo Aquo Albo Carbic Anthroposol
P. Carbic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, with a surface horizon ≥10 cm thick with 2%–17% organic carbon .... Terro Cryo Aquo Fusco Carbic Anthroposol
Q. Carbic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon ≥10–30 cm thick with ≥17% organic carbon and <15% volume artefacts in any horizon .... Modal Carbo Carbic Anthroposol
R. Carbic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon <10 cm thick and <15% volume artefacts in any horizon .... Modal Egeo Carbic Anthroposol
S. Carbic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon ≥10 cm thick with <2% organic carbon .... Modal Albo Carbic Anthroposol
T. Carbic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon ≥10 cm thick with 2%–17% organic carbon and <15% volume artefacts in any horizon .... Modal Fusco Carbic Anthroposol

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Summary key for Technic Anthroposols

A. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10–30 cm thick with ≥17% organic carbon and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Carbo Technic Anthroposol

B. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon <10 cm thick and ≥15% volume artefacts in cumulative ≥30 cm horizons ……… Terro Egeo Technic Anthroposol

C. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10 cm thick with <2% organic carbon and ≥15% volume artefacts in cumulative ≥30 cm horizons………………… Terro Albo Technic Anthroposol

D. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with a surface horizon ≥10 cm thick with 2%–17% organic carbon and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Fusco Technic Anthroposol

E. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Cryo Carbo Technic Anthroposol

F. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon <10 cm thick and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Cryo Egeo Technic Anthroposol

G. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10 cm thick with <2% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Cryo Albo Technic Anthroposol

H. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, a surface horizon ≥10 cm thick with 2%–17% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Cryo Fusco Technic Anthroposol

I. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Aquo Carbo Technic Anthroposol

J. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon <10 cm thick, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Aquo Egeo Technic Anthroposol

K. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10 cm thick with <2% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Aquo Albo Technic Anthroposol

L. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock, poorly to very poorly drained, with a surface horizon ≥10 cm thick with 2%–17% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Aquo Fusco Technic Anthroposol

M. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, with a surface horizon ≥10–30 cm thick with ≥17% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons. ………………… Terro Cryo Aquo Carbo Technic Anthroposol

N. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, a surface horizon <10 cm thick, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Cryo Aquo Egeo Technic Anthroposol

O. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, a surface horizon ≥10 cm thick with <2% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Cryo Aquo Albo Technic Anthroposol

P. Technic Anthroposol composed of anthropogenic material <100 cm deep overlying natural soil or bedrock with permafrost, poorly to very poorly drained, a surface horizon ≥10 cm thick with 2%–17% organic carbon, and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Terro Cryo Aquo Fusco Technic Anthroposol

Q. Technic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon ≥10–30 cm thick with ≥17% organic carbon and ≥15% volume artefacts in cumulative ≥30 cm horizons ……… Modal Carbo Technic Anthroposol

R. Technic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon <10 cm thick and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Modal Egeo Technic Anthroposol

S. Technic Anthroposol composed of anthropogenic material ≥100 cm deep with a surface horizon ≥10 cm thick with <2% organic carbon and ≥15% volume artefacts in cumulative ≥30 cm horizons ………………… Modal Albo Technic Anthroposol

T. Technic Anthroposol composed of anthropogenic material is ≥100 cm deep with a surface horizon ≥10 cm thick with 2%–17% organic carbon and ≥15% volume artefacts in cumulative ≥30 cm horizons ……… Modal Fusco Technic Anthroposol

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