Gelisols: Part I. Cryogenesis and State Factors of Formation

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Editor’s note: This is the first in a two-part series on Gelisols. Part I examines the cryogenesis and the state of formation, and part II in the next issue of Soil Horizons will look at classification and related issues.

Gelisols are soils affected by permafrost. It was the 12th order added to Soil Taxonomy, the U.S. soil classification system. They are classified as Cryosols in both of the World Reference Base and the Canadian System of Soil Classification, and Cryozem in the Russian soil classification system. In the second edition of Soil Taxonomy (1999), Gelisols are defined as soils that have (1) permafrost within 100 cm of the soil surface; or (2) gelic materials within 100 cm of the soil surface and permafrost within 200 cm of the soil surface.

According to A.L. Washburn, a noted geocryologist, permafrost is defined as a thermal regime rather than a material presence. Thus any material—soil, rock, or water in the form of ground ice—that has temperature below the freezing point of water throughout the year for two consecutive years or more is considered permafrost. However, the permafrost material that receives most attention is the ice-cemented permafrost because of the phenomena associated with ice formation, freeze–thaw cycles, and frost heave. To most field soil scientists, in practice, permafrost refers to frozen soils and ice contained in those soils. The permafrost environment has been a challenge to agricultural, urban, and industrial development and more recently has received greater attention because of its unusually high carbon (C) storage and the impact on global climate. Gelisols occupy about 12% of the land surface on earth and store ~30% of the total terrestrial C.

Cryogenesis and Cryostructure Formation

The original intent and reasoning for establishing the Gelisol order was to recognize the presence of ice-cemented permafrost consisting of layers and lenses of segregated ice and different forms of massive ground ice, including ice wedges. The presence of ice is the most limiting factor in human land use practices. Based on thermal regime, a typical Gelisol pedon consists of two parts: the upper part subject to seasonal freeze and thaw called the active layer and the lower part, which is actually the upper permafrost. Soil freezes when the ambient temperature drops below 0°C and soil water moves toward the freezing front. As freezing advances deeper into the soil, horizontally oriented ice layers form with each increment of freezing, resulting in the most common cryostructure—stratified lenses of frozen soil without visible ice and segregated ice layers (ice lens). The thickness of ice lenses vary from <1 mm to >2 cm, the latter of which are called ice belts.

A second freezing front rises from the permafrost below. Toward the end of summer, solar radiation decreases, and the active layer freezes from the bottom upward. Thus soil water in the active layer moves to two different freezing fronts, toward the surface and the permafrost table. Layered cryostructures form in both the upper and lower parts of the active layers, drawing soil water away and leaving the middle part of the active layer relatively dry, with either coarse platy structure or massive conditions.

Soil structure develops in alignment with cryostructure formation. As water moves to the freezing front(s), drying soil shrinks with water loss, causing cracking and formation of vertical ice lenses during further freezing. The horizontal and vertical cracking and ice lens formation result in “ice nets” in which soils are partitioned into elongated platy and blocky structures, which correspond to “lenticular” and “reticulate” cryostructures, respectively, according to geocryologists H. French and Y. Shur. Through freeze–thaw cycles, these