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Properties of volcanic soils in cold climate conditions

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Layers of volcanic ash and the Andosol soils derived from them may play an important role in preserving snow and ice as well as developing permafrost conditions in the immediate vicinity of volcanoes of high elevation or those situated at high latitudes, and land areas, often distant from volcanic activity that are either prone to permafrost or covered by snow and ice, but are affected by the deposition of subaerial ash. The special properties of volcanic ash that are responsible are critically reviewed particularly in relation to recent research in Kamchatka in the Far East of Russia. Of particular importance are the thermal properties and the unfrozen water contents of ash layers and the rate at which the weathering of volcanic glass takes place. Volcanic glass is the most easily weathered component of volcanic ejecta (Shoji et al., 1993; Kimble et al., 2000). There are many specific environmental conditions, including paleoclimate and present-day climate, the composition of volcanic tephra and glaciation history, which cause the differences in weathering and development of volcanic ash soils (Zehetner et al., 2003). The preservation of in situ, unweathered, and unaltered surficial ash-fall deposits in the cold regions has important implications for paleoclimate and glacial history. Ash-fall deposits, which trap and preserve the soils, sediments, and landforms on which they fall, can be used to resolve local climate conditions (temperature and moisture) at the ash site during ash-fall deposition. The preservation of detailed sedimentary features (e.g. bedding in the ash, sharpness of stratigraphic contacts) can tell us about their post-depositional history, whether they have been redeposited by wind or water, or overridden by glaciers (Marchant et al., 1996). Weathering of volcanic glass results in the development of amorphous clay minerals (e.g. allophane, opal, palagonite) but this takes place much slower in cold than under warmer climate conditions.
Only few studies on weathering of volcanic ash and developing volcanic soils under cold climatic conditions were carried out, especially in areas with permafrost (Bäumler, 2003). Most of research on volcanic permafrost soils was done in Yukon (Canada), Kamchatka (Russia), and Antarctica, or on seasonal frost in mountain area in Iceland, Japan, New Zealand, and Ecuador. Soils of Iceland and Antarctica are used as terrestrial analogs to Martian soils (Gooding & Keil, 1978; Allen et al., 1981).
The review of existing data demonstrates that there is a strong correlation between the thermal conductivity, the water-ice content, and the mineralogy of the weathered part of the volcanic ash, enhanced amount of amorphous clay minerals (allophane, palagonite) increase the proportion of unfrozen water and decrease thermal conductivity (Kuznetsova et al., 2012, 2013; Kuznetsova & Motenko, 2014), and amorphous silica does not alter to halloysite or other clay minerals even in ashes of Early Pleistocene age (Kamchatka) or Miocene and Pliocene deposits (Antarctica) due to cold temperatures. The significance of these findings is discussed in relation to the reconstruction of past climates and the influence of volcanic ash on permafrost aggradation and degradation, snow and ice ablation, and the development of glaciers.