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Pedogenesis of tephra-derived soils in Japan

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In Japan, there are still 110 active volcanoes today, which occupy approximately 7 percent of those in the world. Some volcanoes in Japan are erupting now and continuing deposition of tephras on the land surface. They will become the parent material of the soils. Of the soils in Japan, tephra-derived soils 'Kuroboku soils (Andosols/Andisols)' are the second-most common group under the main classification scheme in usage, *the Unified soil classification system of Japan* (FCSCN, 2003). Many tephra-derived soils are distributed near and around numerous volcanoes in Japan. Tephra-derived soils composed of black soils (abundant humic soils), brown soils (mainly brown loamy soils: including tephric loess and loess), and Regosols (Tephric) (FAO, 2006) (very weakly developed mineral soils). It has been suggested that the black soils develop when the supply of organic matter by Gramineae grass exceeds the rate of addition of tephra parent materials (Inoue, 2002). It is usually stabilized by the formation of allophane and Al- (or Fe-) humus complexes. Origin of the abundant humus is confirmed by the high correlation between organic carbon content and phytolith content of Gramineae grass (Inoue et al., 2000; 2001 etc.). Most of the Japanese Holocene tephra-derived soils are rich in humus. Older buried humic-rich soils can also be observed in Late Pleistocene tephra-soil sequence in Japan (Inoue et al, 2011a). One of the tephra-derived soils 'brown soils' having poor in humus include an aeolian-reworked tephras (tephric loess; Pullar and Pollok, 1973) as main parent material. Tephric loess occurs in tephra-soil sequences in Japan and is also interlayered with 'background' loess derived from long-term (continuously-deposited) loess (aeolian dust) deposition from Gobi, Taklamakan desert, and the loess plateau in central Asia (Inoue and Naruse, 1987). This loess is barely observed in Japan. Sase and Hosono (1996) shows that pedogenesis of brown soils occurs under the forest vegetation by using vegetation changes from phytolith composition in tephra-soil sequence.

Pedogenesis includes both 'topdown' and 'upbuilding' models (Almond and Tonkin, 1999; Lowe, 2000; Inoue, 2001). Topdown pedogenesis is 'classical' soil formation that occurs by leaching, illuviation, and other processes that form andic materials with horizons developing in a downward-moving front. Upbuilding pedogenesis operates where the soil forms while additions to the soil surface of such materials as tephra or loess occur. If additions are sufficiently slow — typically as thin incremental deposits in distal areas — then topdown pedogenesis continues while the land surface slowly rises (referred to as 'developmental upbuilding'). If additions are thick or frequent, as typically occurs nearer volcanic sources, then the antecedent soil is buried and isolated, and soil formation begins again on the new materials at the land surface ('retardant upbuilding') (Inoue et al., 2011b; Lowe et al., 2008). The profile character is thus determined by the interplay between the rate at which tephras are added to the land surface and topdown processes. Understanding Andosol/Andisol genesis thus often requires a stratigraphic approach combined with an appreciation of buried soil horizons and polygenesis (Lowe and Tonkin, 2010). The terms 'developmental upbuilding' and 'retardant upbuilding' were first used by Johnson and Watson-Stenger (1987) and Johnson et al. (1990) as part of their dynamic-rate model whereby soils evolve by 'ebb and flow' through time (Schaetzl and Anderson, 2005). As mentioned above, most of the tephra-derived soils in Japan are formed by upbuilding pedogenesis and may be described as multisequal soils.

At the present day, theories concerning pedogenesis of tephra-derived soils in Japan are changing from long-established theories. The soils in the regions having numerous active volcanoes occur distinctive pedogenesis unlike in non-volcanic regions.

Keywords: soil, tephra, pedogenesis, tephra-derived soil, Andosols/Andisols, phytolith