Morphological and Selected Chemical Characteristics of Tephra-derived Soils in Changbai Volcano Area, Northeast China

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Abstract

The morphological and selected chemical properties of 18 pedons developed in Changbai volcano area, Northeast China were investigated. The parent material of these soils consists of thick and coarse tephra deposits from plinian falls, pyroclastic flows and lahar (mudflow) mainly from the 10th century eruption. Although some buried horizons underlying the thick tephra deposit of the 10th century eruption showed clayey soil texture, these soils are characterized by sandy soil texture, A/C type of soil horizon sequence and low acid oxalate-extractable Al+Fe content. Based on the world reference base for soil resources (WRB : FAO, ISRIC and ISSS, 1998), many horizons met some criteria of vitric horizon, while considerable horizons were tephric soil materials. These suggest that the tephra-derived soils in this area is on a young stage of soil development. The cooler climate condition played a major role in the slow soil development. Furthermore, the parent material consisting of the coarse textured tephras provided by the sequential plinian falls and pyroclastic flows, not fine textured volcanic ash, would affect the slow rate of tephra weathering. The soil genesis of the Changbai volcano area is dependent on the properties of the parent material and different climate conditions with elevation.

Introduction

Changbaishan (Baitoushan), locating on the border between China and North Korea, is one of the famous volcanos in China. Changbaishan, the highest peak at 2,691 m above sea level, consists of accumulated pyroclastic materials. The 10th century eruption of Changbai volcano was one of the largest volcanisms in the last 2000 years (Machida et al., 1990; Miyamoto et al., 2002; Wei et al., 2003; Miyamoto et al., 2004). The ejecta (B-Tm : Baito ushan-Tomakomai ash) is found also in northeast Japan, more than 1,000 km from the source (Machida and Arai, 1992). There are a number of studies on volcanic ash soils in Changbaishan (Zhao, 1988; Xie, 1990; Zhao et al., 1993; Zhao et al., 1997; Zhao et al. 2000). Zhao et al. (1993) reported morphological, chemical and humus properties of 5 pedons developed on volcanic ash under cool temperature conditions in Changbaishan. Although they showed that these pedons were characterized by soil horizon sequences of A/Bw/C or A/C and by bright colors in A horizons, their study area was limited to a part of its mountain area consisting of relatively high elevation (1,030 to 2,300 m above sea level) and the contribution of the 10th century volcanism to the parent material of these soils was not considered so much. The purpose of this study is to describe overview of the morphological and selected chemical characteristics of tephra-derived soils in Changbai volcano and to examine the effects of the eruptive sequence of the 10th century Changbaishan eruption on soil formation in this area.

Materials and Methods

The study area is mainly located on the northeastern slopes of Changbaishan in the eastern part of Jilin province. Soil samples were collected from 18 pedons developed on tephra deposits (Fig. 1). Sampling locations of the pedons were selected covering the extensive Changbai volcano area. Elevation range of the pedons are from 430 to 1,500 m and geographical distribution of them are widely spread, which shows lower height and farther distance from the vent of Changbaishan (summit caldera called "Tianchi" lake). The climate in the area strongly depends on elevation. The mean annual temperature at the elevations of 300 to 600 m, 600 to 1,100 m, 1,100 to 1,700 m, 1,700 to 2,000 m and 2,624 m asl are 2.2 to 4.8, -0.3, -2.9, -4.4 and -7.3 ° C, respectively (Mao, 1989). The mean annual precipitation is about 518 to 857 mm at 300 to 600

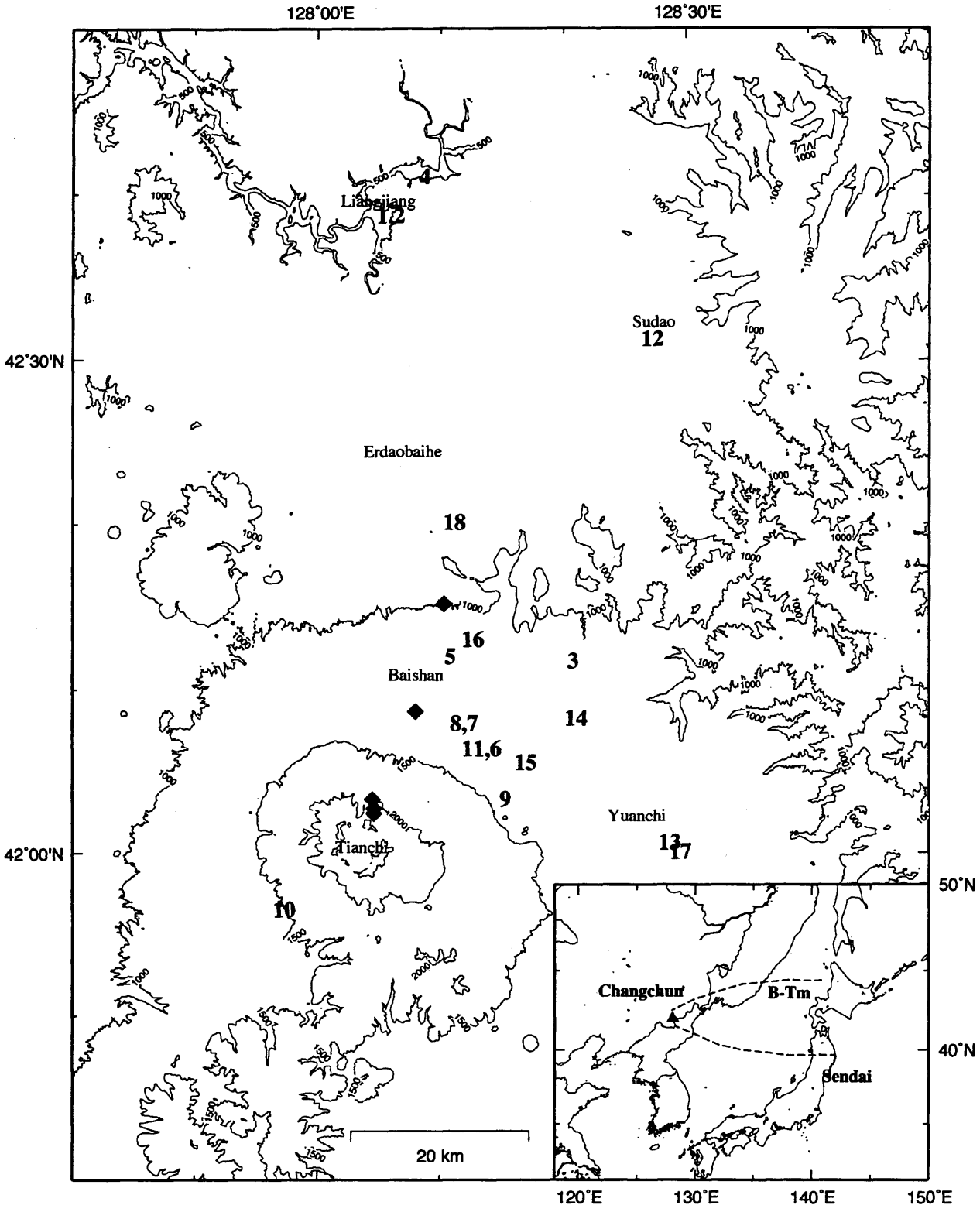

Fig. 1 Geographical locations of the areas surveyed in Changbaishan, northeast China. Number symbols of 1 to 18: location of pedons. ◆: location of pedons described by Zhao et al. (1993). B-Tm: distribution area of Baitoushan-Tomakomai tephra deposited after the eruption of the Changbaishan volcano in 10th century (Machida and Arai, 1992).

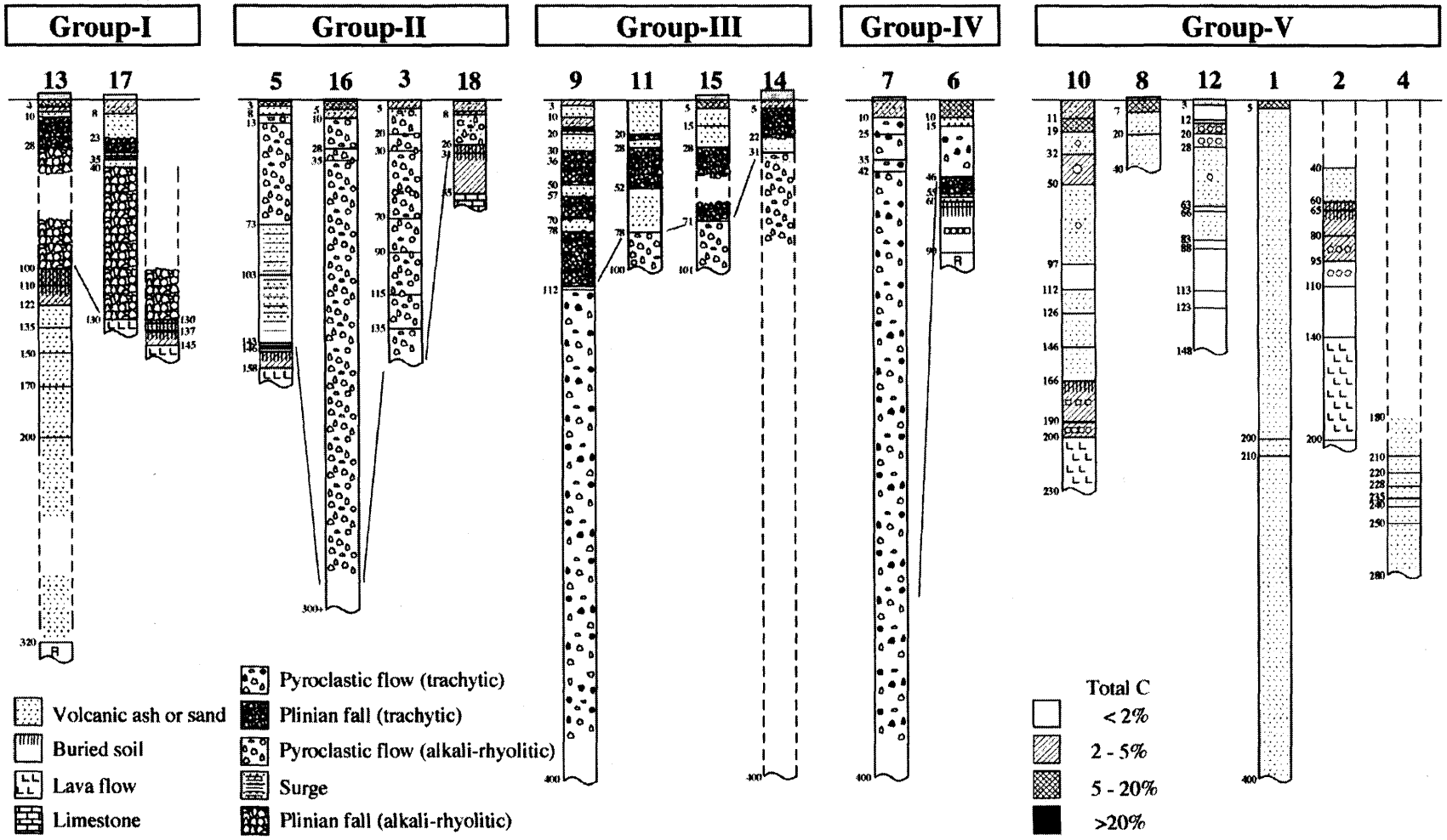

Fig. 2. Profile sections of the tephra-derived soils in Changbai volcano area. The numbers on and beside the sections indicate the sampling sites as described in Fig. 1 and the depth (cm) from the surface, respectively. Group-Ⅰ : soils from trachytic plinian fall over alkali-rhyolitic plinian fall. Group-Ⅱ : soils from alkali-rhyolitic pyroclastic flow. Group-Ⅲ : soils from trachytic plinian fall. Group-Ⅳ : soils from trachytic pyroclastic flow. Group-Ⅴ : soils from lahar deposit.

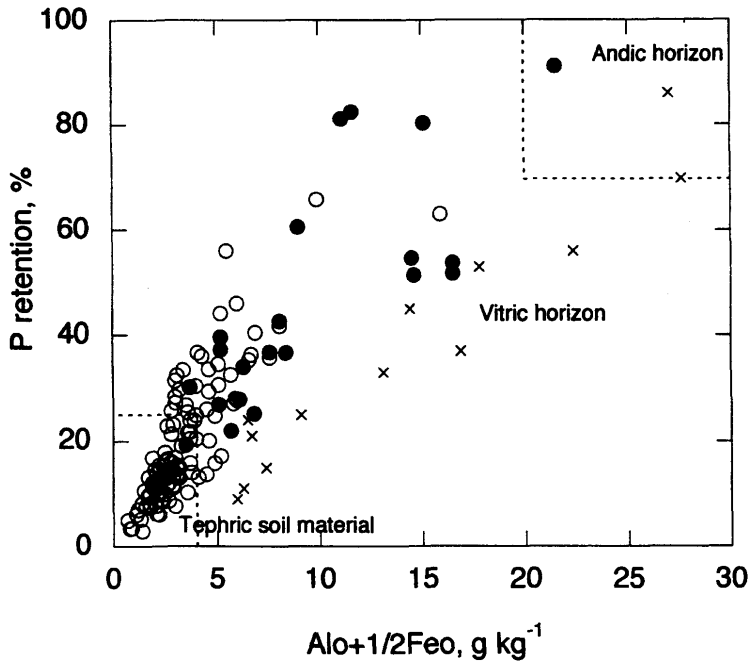

Fig. 3 Relationship between P retention and the amount of acid oxalate-extractable Al plus 1/2 Fe in the Changbaishan soils. Open circles: surface and subsurface horizon (n=111). Closed circles: buried horizon (n=24). ×: data of Changbaisan by Zhao et al. (1993) with the exception of the C horizon soil from the C-2 pedon (n=13). Dashed line show the criteria of andic horizon, vitric horizon and tephric soil material (FAO, ISRIC and ISSS, 1998).

m asl and increases with elevation to about 1,333 mm at 2,624 m asl with maximum values of 1,630 mm in the summit caldera. The vegetation is also related to the elevation. Pedons were sampled and described according to horizonsor layers, air-dried, and passed through a 2-mm sieve. Total carbon (C) was determined by dry combustion. Particle size distribution was measured by the sieving and pipette method. P retention and acid oxalate-extractable Al and Fe content was determined by the method described by Blakemore et al. (1981).

Results and Discussion

Fig. 2 shows the profile sections of the pedons. The Changbaishan soils consist of thick and coarse tephra deposit mainly from 10th century eruption. In some pedons, there were buried horizons covered by the tephra deposit. Sequential eruptions of the 10th century volcanism could be divided into two stages, whose magma composition changed from alkali-rhyolitic to trachytic (Machida et al., 1990; Miyamoto et al., 2002). According to the stratigraphy of the 10th century eruption proposed by Miyamoto el al. (2004), we distinguished five groups of tephra-derived soil by the major parent material as follows : soils from the trachytic plinian fall over the light-colored alkali-rhyolitic plinian fall (group I), the light-colored alkali-rhyolitic pyroclastic flow (group II), the trachytic plinian fall (group III), the dark-colored trachytic pyroclastic flow (group IV) and lahar (mudflow) deposit (group V).

The soils from the plinian fall deposit (Group I and III) were distributed in a specific direction of mountainous area along the main axis of a each eruption. The alkali-rhyolitic pyroclastic flow, called "unit C" by Miyamoto et al. (2004), was provided far and wide at the early stage of 10th century volcanism and covered by the later ejecta. Therefore, the group-II soils were found at a distant foot-slope of Changbaishan. Group-IV soils were found at the restricted area since the trachytic pyroclastic flow, called "unit F", flowed along valleys selectively. The soils from lahar deposit was observed in the both far and near areas of Changbaishan. Around Liangjiang

town along the Erdaobaihe river, 70 km north from the summit caldera, we found the soils developed from thick and coarse lahar deposit.

The mountainous soils were characterized by soil horizon sequences of A/C with sandy soil texture reflecting the properties of the parent material (data not shown). These suggest that the tephra-derived soils in this area is at a young stage of soil development (Zhao et al., 1993; Shoji et al., 1993). The soils in a distant area derived from the lahar deposits also showed weak soil development. Some buried horizons underlying the thick tephra deposit of 10th century eruption showed clayey soil texture. Fig. 3 shows the relationship between P retention and the amount of acid oxalate-extractable Al+1/2Fe (Alo+1/2Feo) of the Changbaishan soils including the data of Zhao et al. (1993). The values of Alo+1/2Feo in surface and subsurface horizons tended to be lower than those of buried horizons.

Alo+1/2Feo and P retention of almost all horizons or layers were less than 2% and 70%, respectively (Fig. 3). Based on the world reference base for soil resources (WRB : FAO, ISRIC and ISSS, 1998), many horizons met some criteria of vitric horizon (Alo+1/2Feo > 0.4% or P retention > 25%), while considerable horizons fell within the range of tephric soil material (Alo+1/2Feo < 0.4%). Clay contents of most soil horizons or layers were less than 10%. These features also indicate that the soils in the Changbai volcano area still remain at the young stage of soil development. The relationship between age of volcanic ash soils and their soil development in northeastern Japan indicates that the volcanic ash soils older than 1000 years have a horizon with more than 2.0% and 85% of Alo+1/2Feo and P retention, respectively, as well as humic surface and Bw horizon (Shoji et al., 1993). However, the Changbaishan soils, whose soil age would be more than 1000 years old, show the earliest stage of pedogenesis. The cooler climate condition of this area might be a major factor of the slow soil development. Furthermore, the parent material consisting of the coarse textured tephras provided by the sequential plinian falls and pyroclastic flows, not fine textured volcanic ash, would affect the slow rate of tephra weathering. Further studies to examine the effect of the parent material and local climate on the soil genesis of tephra-derived soils in Changbai volcano area are required.

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