Geoderma 235–236 (2014) 48–58

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

A pedogeographical view of volcanic soils under cold humid conditions: the Commander Islands

Anton Ivanov [a], Serghei Shoba [a], Pavel Krasilnikov [a,b,c,*]

[a] Faculty of Soil Science, Lomonosov Moscow State University, Moscow, Russia
[b] Eurasian Center for Food Security, Lomonosov Moscow State University, Moscow, Russia
[c] Institute of Biology, Karelain Research Center of RAS, Petrozavodsk, Russia

ARTICLE INFO

Article history:
Received 21 April 2014
Received in revised form 26 June 2014
Accepted 29 June 2014
Available online 8 July 2014

Keywords:
Volcanic ash
Sedimentation
Podzols
Andosols
Micromorphology

ABSTRACT

We studied two representative profiles at the Bering Island, the Commander Archipelago in the north of the Pacific Ocean. The soils developed in the material of predominantly volcanic origin under cold humid marine climate. One of the soils was classified as an Andosol, and the other as an Albic Podzol. The two soils showed certain similarity in the morphology and properties, thus supporting the hypothesis of their common pedogenetic origin. The study of the composition of a coating of a sand grain indicated complex path of the genesis of the soils: initially the coatings have been formed by allophanes with Fe–humus complexes, then by allophanes with humus, and then by Fe–humus and Al–humus components. The analysis of the total elemental composition, the distribution of the size fractions, and the previously reported data on the mineralogical composition of the soils allowed suggesting a significant contribution of the external volcanic ash from the Kamchatka Peninsula in the genesis of the soils of the Commander Islands. Most probably the whitish layer includes acid volcanic glass transported by the wind. The soils of the (sub)mountainous areas lack whitish layers because of erosion. However, the soils under study do not represent mere mixtures of different ash layers: the newly deposited material was evidently incorporated in the soil profile. We conclude that volcanic soils are specific natural bodies, where sedimentary processes should be taken into account along with the pedogenesis.

1. Introduction

The volcanic soils differ from the soils formed in other parent materials. Their genesis and properties depend on their age, on the composition and percentage of volcanic material, and on the bioclimatic conditions. However, even the relation between pedogenesis and climate differs in soils formed in volcanic and non-volcanic sediments. The main difference in the course of pedogenesis in volcanic and non-volcanic deposits is in the intensity of weathering: most of the varieties of volcanic glass weather quickly producing excessive concentrations of Si and Al in soil solution (Nanzyo et al., 1994). These elevated concentrations of Si and Al result in the precipitation of poorly ordered components in soil such as allophanes, imogolite, and Al–humus complexes (Yost and Fox, 1981). Allophane and imogolite are soil minerals with pH-dependent charge, which form stable complexes with organic matter. These components are responsible for specific physical and chemical properties of volcanic soils, such as thixotropy (the property of clays to behave like liquids under pressure), high water retention capacity, the absence of clay illuviation, intensive organic matter accumulation and strong phosphorus retention (Shoji et al., 1994). Even under humid acid environments these soils do not have evidences of the eluvial–illuvial profile differentiation (Sedov et al., 2003, 2010). It was noted that in humid coniferous forests the volcanic soils have even thicker and darker A horizon than under graminaceous vegetation. This difference is the main reason why the volcanic material-derived soils are regarded as special taxa on the highest level of taxonomy in the majority of soil classifications (Krasilnikov et al., 2009). Thus, the properties of the soils derived from volcanic ash cannot be easily extrapolated basing on the knowledge on the characteristics of non-volcanic soil in similar environments.

Actually the peculiar features of soils formed in volcanic sediments are well documented for most environments, from humid tropics to subarctic deserts (Sedov et al., 2010; Shoji et al., 1994). However, some specific environments are not sufficiently documented and explained in the terms of pedogenetic processes. For example, it is still unknown what properties of volcanic soils are typical for humid subarctic conditions, like in the Commander Islands in the northern part of the Pacific Ocean. Only few publications on the soils formed under similar conditions at the Aleut Islands (Ping et al., 1988) and in some places of the Kamchatka Peninsula (Karpachevsky et al., 2009) are available. Unfortunately, the paper on the soils of the Aleut Islands lacks data for pedogenetic interpretation, and the soils of Kamchatka form under the

* Corresponding author at: Eurasian Center for Food Security, Lomonosov Moscow State University, Moscow, Russia.
E-mail address: krasilnikov@ecfs.msu.ru (P. Krasilnikov).

http://dx.doi.org/10.1016/j.geoderma.2014.06.031
0016-7061/

conditions of continuous volcanic ash accumulation (Zakharikhina and Litvinenko, 2013) that is not typical for many other areas. Thus, the Commander Islands give a unique opportunity to study the soils that form in partly pyroclastic material under cold humid environments. This paper aims at the characterization of the morphology and chemical properties of the soils of the Commander Islands affected by volcanic ash sedimentation, and interpretation of their pedogenetic properties. We believe that this study would help in understanding the global distribution and pedogenesis of volcanic soils.

2. Materials and methods

2.1. Study area

The study was made at the Bering Island, the biggest one in the Commander Archipelago. The island is located 55°00′ N and 166°15′ E (Fig. 1). It stretches from SE to NW for more than 100 km and its total area is 1667 km^2. The Commander Islands are emerged fragments of a mountainous range. The topography of the Bering Island was formed by tectonic movements and further denudation processes; a small northern portion of the island is represented by denudation plains and alluvial terraces (Ponomareva and Isachenkova, 1991). The highest point is the Steller Mountain at 751 m above sea level.

The bedrocks of the island include andesite–basalt and tuff-like materials; the latter are represented by a sequence of layers of sandstones, siltstones, argillites, conglomerates, lava flows and tuffs (Tsvetkov et al., 1990). The northern part of the island consists mainly of Paleogene–Neogene volcanogenic materials, mostly andesite–basalt and tuffs, and the southern part has mostly tuff-like sedimentary rocks. Mineralogical composition of these rocks is characterized by the dominance of basic plagioclases with a significant proportion of zeolites, volcanic glass, orthorhombic and monoclinic pyroxenes. In Pleistocene the islands have been covered with ice caps; the deglaciation of the islands occurred between 10 and 12 ka BP. (Black, 1981). The Commander Islands are located close to the Kamchatka Peninsula known for its active volcanism, thus the territory of the islands received some deposits of fresh volcanic ash of various composition. The volcanic cones can be seen in Fig. 1, and the list of active volcanoes of the peninsula is presented in Table 1. The major stratovolcanoes such as Shiveluch and Avachinsky erupted from 3 to 5 times during the Holocene, each time producing tephra volume of several cubic kilometers (Braitseva et al., 1995). The study of a peat column at the Bering Island showed the presence of 12 volcanic ash layers accumulated during the last 10,000 years (Kiryanov et al., 1986). The thickness of the individual ash layers varied from 0.5 to 7 cm.

Though the archipelago is located at relatively low latitude, corresponding to such cities as Moscow or Copenhagen, the cold waters of the Bering Sea and the Pacific Ocean determine cool and humid climates of the isles (Shear, 1964). The mean annual temperature is 2.1 °C with the lowest mean monthly value of −4 °C in February and the highest value of 10.5 °C in August. Frost-free period varies between 127 and 139 days per annum. The annual precipitation is 470 mm, in warm period the rainfalls are represented by drizzly rains (0.1–0.5 mm per day). The relative air humidity is usually higher than 90%, and additional moisture enters soils with mists that are especially common in the summer period. In winter the snow cover reaches 80 cm, and in some hollows may reach 10 m. In general the difference in the distribution of heat and precipitation between the summer and winter periods is not very strong (Fig. 2).

The most abundant vegetation of the slopes of the mountain ranges is represented by heather and motley grass — subshrub communities. The toeslopes and depressions are occupied by subshrub and motley

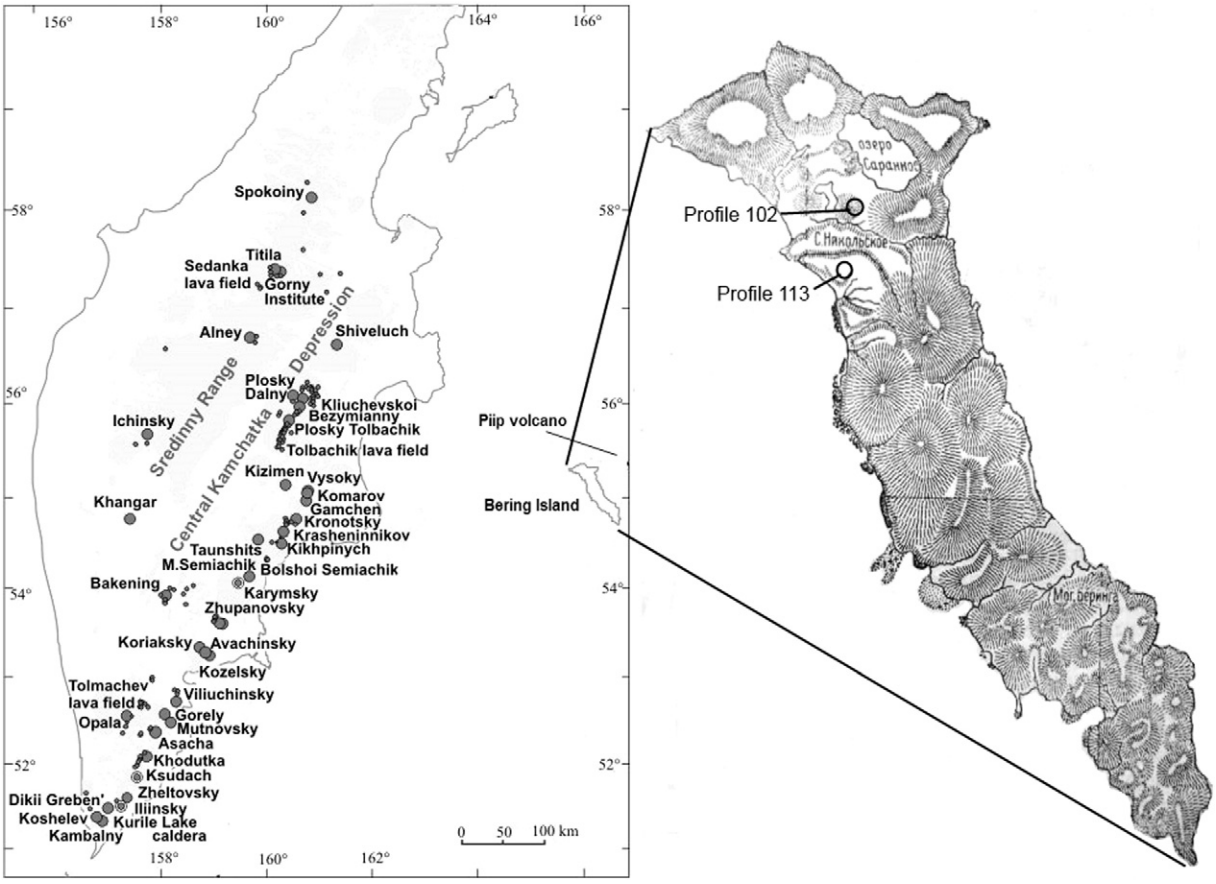

Fig. 1. The location of the Commander Islands, a schematic map of the Bering Island and the location of soil pits. The Holocene volcanoes are reproduced with permission from the map prepared by the Institute of Volcanology and Seismology of Russian Academy of Sciences (http://www.kscnet.ru/ivs/volcanoes/holocene/main/main.htm).