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Clay mineralogy, cation exchange capacity and specific surface area of loess soils with different volcanic ash contents

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Abstract

The loessical soils of the semiarid Argentinean Pampas (SAP) contain variable amounts of volcanic ashes. Their influence on the mineral composition and some physicochemical properties of soils like soil specific surface area (SSA) and cation exchange capacity (CEC) have been still not elucidated. Because of that we analyzed 24 topsoil samples (0 to 20 cm) of soils with high and low volcanic ashes contents for clay mineralogy and its influence on soil chemical and physical properties and CEC and SSA. Results showed that ash enriched soils were placed to the south and ash free soils to the north-east of the SAP in agreement with the volcanic ash deposition pattern of 1932 Quizapu vocano eruption. Mineralogy of the clay fraction was dominated by amorphous minerals and less crystallized and expansible smectites in ash enriched soils, and by illites in ash free soils. No differences in crystallinity or expansibility were found between montmorillonites of ash free and ash enriched soils. Fine sized clays (<0.2 μm) were dominated by illites and illite–montmorillonite intergrades in ash free soils and by amorphous materials in ash enriched soils. Such results indicated that montmorillonites tend to form more when volcanic ashes are present but their crystallinity and expansibility do not change with ashes content. SSA was positively related with silt contents in both ash free and ash enriched soils ($r^2=0.70$, $p<0.05$). The clay fraction (<2 μm) explained only 9% of SSA variability and the fine clay fraction (<0.2 um) did not affect SSA. The influence of silt on SSA was attributed to the existence of 2 : 1 minerals in the silt fraction. These results also indicated that ash contents did not influence SSA. CEC correlated positively with clay ($R^2=0.67$, $p<0.001$) in ash enriched soils, and with organic matter in ash free soils ($R^2=0.837$, $p<0.001$) but it did not correlate with fine clay contents in any of both soil types. These trends were explained on the basis of the higher CEC conferred by smectites in ash enriched soils and by OM in ash free soils. It can be deduced that soil degradation processes producing losses of fine sized particles, like wind or water erosion, will decrease SSA in both the ash enriched and the ash free soils, but only CEC in ash enriched soils. Organic matter losses due to excessive cultivation will decrease CEC in ash free soils.

Keywords: Semiarid soils; Amorphous minerals; Illite; Cationic exchange capacity; Specific surface area

1. Introduction

Soils of the semiarid Argentinean Pampas (SAP) develop on Holocene loessical sediments with variable volcanic ash contents (Teruggi, 1957). The latest ash depositing eruption occurred in 1932, when the "Quizapu" volcano (located in the Andes) accumulated

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a 10 cm thick, 1000 km long and 30 to 50 km broad W–E oriented ash layer, which extended from the Andes to the Central Pampas (Larsson, 1936). This ash layer was mixed with the loessical parent material by tillage operations in cultivated soils.

In general, little is known about the influence of volcanic ashes on soil properties in the SAP, particularly with respect to the influence of ash on clay mineralogy and related physicochemical properties, such as the soil's specific surface area (SSA) and cation exchange capacity (CEC). Buschiazzo and Taylor (1993) found that the clay content of soils of the SAP are highly affected by soil management; as wind and water erosion remove the finest soil particles from the soil, textural changes produce changes in both SSA and CEC. Buschiazzo et al. (1998) found that the amount of amorphous aluminum, and the capacity of the soil to adsorb phosphates, increased with the amount and age of ash. Nearby in the subhumid Argentinian Pampas, the clay fraction of soils with low volcanic ash contents is dominated by illite and poorly crystallized smectites, which are mostly illite–smectite intergrades (del Blanco et al., 2003; Peinemann et al., 2000). Because of similar parent materials in both the subhumid Pampas and the SAP (Buschiazzo, 1988) it could be expected that the soil clay mineralogy of the SAP region would also contain similar amounts of illites and poorly crystallized smectites as compared to the subhumid Pampas.

The formation of smectites from ashes is not well understood. During the weathering process, illite and volcanic ash can develop into smectites via processes such as K-loss from illite interlayers and isomorphic substitution in the Si tetrahedron. As the illites weather the smectites form and the amount of mineral species in the fine clay fraction increases. This can occur also via direct precipitation from the soil solution, however the co-existence of illite and volcanic ashes in most soils does not allow the quantification of the relative contribution of illite and volcanic ashes to smectite formation (Borchardt, 1977). Since in the SAP both ash enriched and ash free soils coexist, the relative contribution of illite and volcanic ashes to smectite formation could be analyzed and compared in order to derive better knowledge of this weathering sequence.

Examining changes in soil properties such as SSA and CEC, due to ashes, in conjunction with clay mineralogy could lead to an improved understanding of the necessary modifications for promoting soil fertility.

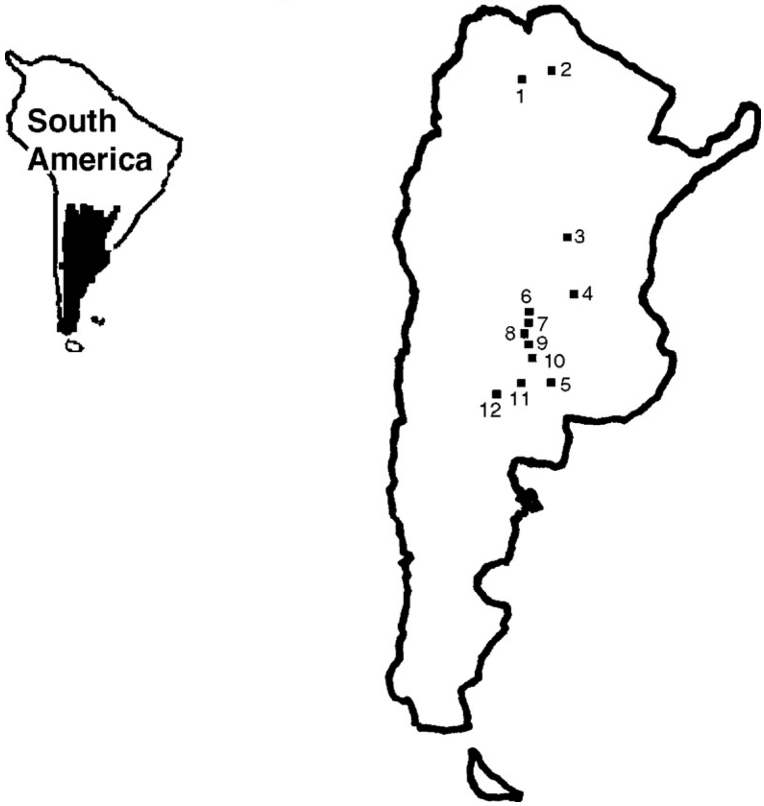

Fig. 1. Location of the studied sites.