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SCIENCE DIRECT

Geoderma 127 (2005) 114–129

GEODERMA

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Clay mineralogy of the soils in the south Ecuadorian páramo region

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Received 23 February 2004; received in revised form 23 November 2004; accepted 29 November 2004
Available online 4 January 2005

Abstract

The páramo soils of the mountainous upper Andean region (>3300 m a. s. l.) of the Rio Paute basin in central Ecuador are characterized by a thick, dark, highly organic epipedon and are classified as Andosols and Histosols. Their high water retention and buffering capacity play a key role in the hydrology of the region, which is subject to land use changes and increased cultivation. In the west (Western Cordillera), the soils are largely formed in the late Miocene and Pliocene volcanoclastic Tarqui formation, while in the east (Central Cordillera) they are formed in an older, mostly intermediate low-grade metamorphic rocks. Ten soil profiles were sampled and studied, using extraction techniques (oxalate and pyrophosphate) and XRD-techniques. Major differences in composition of the clay fractions were found that allow for distinction of three main groups of páramo soils. A first group consists of soils influenced by recent volcanic ashes and dominated by organometallic complexes and with minor but distinct amounts of degraded mica, most probably formed by weathering of primary mica, present in these ashes. The second group comprises soils formed in volcanoclastic material of various Tertiary and earlier formations, containing residual primary and secondary crystalline clay-size minerals, as well as organometallic complexes whose genesis can be linked to the abundant presence of easily weatherable materials in these formations. A third group consists of soils in relicts of Tertiary, highly weathered regolith, formed under humid tropical conditions before the Andean uplift and occurring in the Central Cordillera. These soils contain kaolinite and gibbsite and develop into Histosols in the absence of significant organometallic complexation.

Keywords: Clay mineralogy; Organometallic complexes; Páramo; Andosols; Histosols; Ecuador

1. Introduction

Soils of the high altitude tropical grasslands or páramo's of the Northern Andes have thick, dark, highly organic epipedons, largely because of the cold and wet climate and the resulting poor decomposition of organic matter. An additional factor is the wide-

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doi:10.1016/j.geoderma.2004.11.021

spread occurrence of recent volcanic ashes, giving rise to extensive development of Andosols through weathering of these ashes to specific soil compounds that bind organic matter and thus limit decomposition, notably allophanes and other high alumina secondary minerals. A particularly interesting situation occurs in the Rio Paute basin (Cuenca, middle Ecuador) that lies in the border zone of the recent volcanic ash deposits from the major volcanoes in central Ecuador, including the Sanguay and Tungarahua. In the north of this basin, the páramo soils contain a fair amount of volcanic ash and can largely be classified as non-allophanic Andosols, while to the south and east they grade into volcanic ash free Histosols (Buytaert, 2004), developed on sedimentary and low grade metamorphic rocks.

The páramo region is threatened by both erosion and soil degradation due to land use changes and cultivation practices brought about by increasing population pressure and land expansion (Hofstede, 1995). These risks are studied in a joint program on soil and water management in the Rio Paute basin (PROMAS) executed by the Universities of Cuenca (Ecuador) and Leuven (Belgium). These land use changes have a significant impact on the water regulation capacity of the páramo. Soil structure degradation may lead to changes in water retention and hydraulic conductivity (Buytaert et al., 2002; Buytaert, 2004), as well as increased hydrophobicity and water erosion sensitivity (Poulenard et al., 2001). In the Rio Paute basin, the soil physical properties show regional patterns that appear to be connected with differences in soil parent material (Buytaert, 2004).

Soil physical properties are known to be influenced by the mineralogy of the soils concerned, more particularly that of their clay fraction. For the Rio Paute basin, major differences in composition of these clay fractions can be expected to occur in connection with large differences in parent material. However, as will be elucidated further on, very limited information is available on the clay mineralogy of the soils in the area concerned and, in fact, for Ecuador as a whole; the rare existing studies concentrating on selected Andosols. This paper concerns a first regional study of the clay mineralogy of Ecuadorian páramo soils, among which soils that are not developed in recent volcanic ashes, and aims to provide some insight into the range of clay mineral assemblages that may be encountered in this region and environment.

2. General information

2.1. Study area

The area of study is the páramo of the Rio Paute basin (Fig. 1), which forms part of the Austro Ecuatoriano, the southern Ecuadorian Andes region between 2° 15′ and 3° 30′ latitude South. Due to its harsh climate, steep topography and poor accessibility, the páramo (above 3300 m a.s.l.) was an almost uninhabited and desolate area (Fig. 2) that was only used for extensive cattle grazing. Because land pressure rises in the central valley and the páramo is gradually being opened up, intensive grazing and cultivation are increasing.

In Ecuador, the Andes is subdivided into two ridges separated by a tectonic depression: the Western and Central Cordilleras. The Eastern Cordillera forms a much less prominent ridge and only further north, in Colombia, reaches the dimensions of the other Cordilleras. The tectonic uplift of the Cordilleras, which amounts to more than 3000 m, started in the late Miocene and continues until today. The geology of the South Ecuadorian Andes is relatively simple: on the Pacific side, the oldest rocks consist of sedimentary deposits and basic to intermediate volcanic deposits that during the Cretaceous and Early Tertiary were emplaced in a submarine environment, constituting the Macuchi formation. On the continental side, the Central Cordillera has a Palaeozoic and possibly Precambrian basement. Later during the Tertiary, but prior to the start of the tectonic uplift, this basement and the Macuchi formation were covered by a sequence of intermediate and acid volcanic rocks. Once orogenesis started and the Cordilleras originated, volcanoes covered the emerging ridges with pyroclastics, while the interandean depression was filled with a thick sequence of Plio-Pleistocene fluviatile and lacustrine deposits (Barberi et al., 1988; Coltorti and Ollier, 2000). These mostly volcanoclastic sediments are interlayered with lava flows, agglomerates and pyroclasts.

Prior to the major uplift during the Pliocene and Early Quaternary, the rocks of the central range were