THE 10 Å TO 7 Å HALLOYSITE TRANSITION IN A TROPICAL SOIL SEQUENCE, COSTA RICA

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Abstract—Soils developed on Pleistocene andesitic lava flows and fluvial detritus in the Atlantic coastal plain of Costa Rica display a clay mineral assemblage that includes 10 Å and 7 Å halloysite and lesser amounts of kaolinite and dioctahedral vermiculite. Other secondary minerals include gibbsite, goethite, hematite, maghemite, allophane and amorphous Al hydroxides. Active floodplain soils are dominated by 10 Å halloysite and contain less allophane, while soil clays from Pleistocene terraces consist of a mixture of 10 Å and 7 Å halloysite as well as less dioctahedral vermiculite, kaolinite, and amorphous Al hydroxides. Residual soils formed on Pleistocene lava flows are dominated by 7 Å halloysite with less abundant kaolinite, dioctahedral vermiculite, 10 Å halloysite and amorphous Al hydroxides. This sequence suggests transformations of 10 Å halloysite to 7 Å halloysite and allophane to amorphous Al hydroxides with time. The presence of 10 Å halloysite in Pleistocene terrace soils implies slow reaction rates or metastability. Quantitative X-ray diffraction (QXRD) analysis indicates a decrease in the amount of plagioclase feldspar from 34 wt.% in the 1–2 year floodplain to 0–1.6% in terrace and residual soils. Plagioclase weathering is paralleled by the formation of dioctahedral clay, allophane and Al hydroxides. Analysis by QXRD also indicates that crystalline minerals comprise 70–95% of the soil fraction, implying 5–30% X-ray-amorphous material. These data are verified by selective extraction using ammonium oxalate, which indicates 8–30% amorphous material. Chemical analysis of the extractant by inductively coupled plasma-atomic emission spectrometry indicates that allophane (Al:Si ratios of 0.92–3.82) occurs in floodplain and some terrace soils while amorphous Al hydroxides appear to coexist with allophane in Pleistocene terrace and residual soils with Al:Si ratios of 6.53–8.53. Retention of Mg to a greater extent than Na, Ca and K suggests Mg incorporation into hydroxide sheets in dioctahedral vermiculite as well as substitution into hydroxides.

Key Words—Allophane, Andesite, Costa Rica, Halloysite, Kaolin, Soil, Terrace, Tropical, Vermiculite, Weathering.

INTRODUCTION

One of the most important controls on clay mineral development is leaching intensity during soil formation (Jackson, 1964; Barshad, 1966; Birkeland, 1969). The 1:1 dioctahedral phyllosilicates, gibbsite and short-range order silicates and hydroxides are among the most commonly formed minerals in humid and tropical climates (Mizota and Van Reeuwijk, 1989; Wada, 1989; Quantin et al., 1991). Halloysite with variable d001 values (7–10 Å) and kaolinite are commonly identified 1:1 clay minerals in tropical soils, but the genetic relationship between the minerals remains confused because of high variability in the types and magnitudes of defects that can be present (Brindley and Brown, 1980; Churchman, 1990). Several studies have documented a reduced abundance of halloysite relative to kaolinite with increasing age (Parham, 1969; Eswaran and Wong, 1978; Calvert et al., 1980), yet in other cases researchers have found that kaolinite transforms to halloysite (Robertson and Eggleton, 1991; Singh and Gilkes, 1992). Hughes (1980) documented examples of weathering sequences where kaolinite increases in abundance at the expense of halloysite, but also cases where halloysite forms at the expense of kaolinite. The work of Delvaux et al. (1990) and Watanabe et al. (1992) suggested that interstratified halloysite-smectite is an intermediate weathering product in the conversion of 2:1 swelling clays to 1:1 clays and Fe oxides. Righi et al. (1999) reported on the formation of kaolinite-smectite (K-S) mixed layers at the expense of basaltic parent material in a temperate climate. The complex and varied nature of weathering products, especially in temperate and humid tropical environments, has created difficulty in the identification of standard weathering sequences of aluminosilicate minerals. This paper reports on a halloysite-rich tropical weathering sequence found in lateritic soils developing on andesitic lava flows and alluvial deposits of similar chemical composition.

STUDY AREA

The study site is located near the town of Puerto Viejo de Sarapiquí, Costa Rica, on the grounds of the Organization for Tropical Studies (OTS) La Selva Research Center. Situated at the confluence of two major rivers, the Rio Sarapíqui and Rio Puerto Viejo, the