Mineralogy of Soils Overlying the Two Main Geologic Provinces of the El Yunque National Forest, Puerto Rico

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Abstract

A total of 20 soil samples have been analyzed using XRD analysis to determine their mineral content. Qualitative and quantitative analysis of the data show that all the samples contain quartz, orthoclase, kaolinite, dickite, halloysite and nicrite, gibbsite, augelite, metavariscite, goethite, tsaregorodtsevite, apophylite. Soil sample from Oxisols sites contain higher % of clay minerals than the samples from Dystrudepts sites. Furthermore, the general pattern of the % of total clays, feldspars, and gibbsite within each and between transects suggest that soils in the valleys are more weathered and leached than soils from ridges. The % increase of phosphate minerals in the soils follow that of clay minerals which is most probably due to the attachment of the phosphate minerals to clay mineral surfaces. The presence of the organic cation Tetramethylammonium in the cavities between the oxygen-silicon tetrahedra of the tsaregorodtsevite structure (feldsphoid-zeolitic structure) is consistent with a low energy mechanism for the sequestration of carbon and nitrogen in the EYNF soils.

Introduction

Soil form by weathering of rocks at earth's surface. Samples in this study were collected from soils underlain by silicate bedrock. The following general formulas show the formation of clay minerals and hydroxides from silicate rocks:

$$\underbrace{2KAlSi_3O_8}_{\text{orthoclase}} + 2H^+ + 9H_2O \rightarrow \underbrace{AlSi_2O_5(OH)_2}_{\text{kaolinite}} + \underbrace{4H_4SiO_4^0}_{\text{dissolved silica}} + 2K^+ \quad \text{Eq.1}$$

$$\underbrace{AlSi_2O_5(OH)_2}_{\text{kaolinite}} + 5H_2O \rightarrow \underbrace{2Al(OH)_3}_{\text{gibbsite}} + 2H_4SiO_4^0 \quad \text{Eq.2}$$

From above equations it is clear that the characterization of soils mineral content can aid in an improved understanding of the physical and chemical differences between soils and consequently their developmental history. The main purpose of this study is to determine the mineralogy, qualitatively and quantitatively, of whole soil samples overlying two different bedrocks from EYNF in Puerto Rico. The data obtained from this analysis will help answer the following questions:

1. Is there difference between the clay mineralogy of soils overlying the two different bedrocks?
2. Is there difference in the % of total clay, feldspars, and gibbsite within each and between different transects?
3. To investigate the presence or absence of non-silicate minerals which could play a factor in determining the nutrient pool of the soil.

Description of the Study Area

Puerto Rico is at the eastern end of the Greater Antilles island arc located between the Caribbean Sea and the North Atlantic Ocean. The EYNF is located in northeastern Puerto Rico. Volcaniclastic rock and quartz diorite are the two types of bedrock in the study area. Much of the soil formed on the quartz-diorite parent material is defined as Dystrudepts (a suborder of the Inceptisols). The soil collected from the Volcaniclastic rocks area is Oxisols.(Fig. 1)

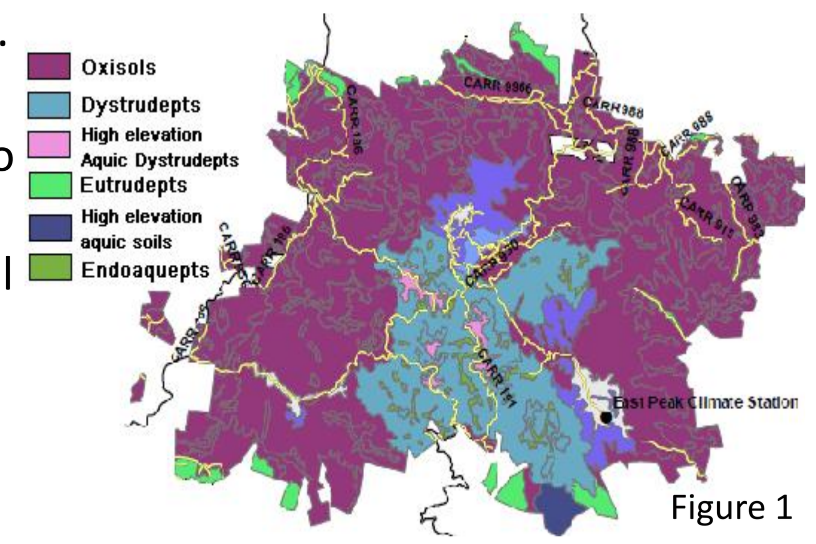

Figure 1

Methods

Twenty samples used in this study were collected from soils overlying two major parent materials in the EYNF in Puerto Rico along ten transects. Each transect consist of two samples with elevation difference of ~5-30m. The higher elevation samples are designated with R (ridge) and lower elevation samples are designated with V (valley). In the laboratory, soils were air-dried and passed through a 2mm sieve. The ball-mill grounded whole soil sample and separated clay-size fraction for each sample are used for X-ray diffraction (XRD). Col Ox 1-4 clay-size fraction was treated to remove organic matter and Fe-oxides for comparison of the XRD Pattern.

Highscore software was used to obtain a list of the possible mineral that best fit the peaks in the XRD pattern obtained for each sample. Quantitative analysis for each sample was carried out using Rietveld analysis.

Discussion

The qualitative XRD analysis indicate the presence of the following minerals in the whole samples and the clay-size fractions: quartz, orthoclase, clay minerals (kaolinite, dickite, halloysite and nicrite), gibbsite, phosphate (augelite and metavariscite), goethite, tsaregorodtsevite, apophylite.

As discussed in Introduction, the presence of the clay minerals, feldspars, and gibbsite are excellent indicators of the degree and history of the weathering of the bedrock and the formation of soils overlying it. Therefore, in the following discussion thy will be discussed in relationship to each other.

The quantitative XRD analysis of soil samples from ridge have higher total clay content than the samples valley, while gibbsite show the opposite relationship to that of clay as shown in Figure 2A&B. Further, the feldspar in the valley and ridge samples in the two bedrock sites are near equal amounts (Figure 2C).

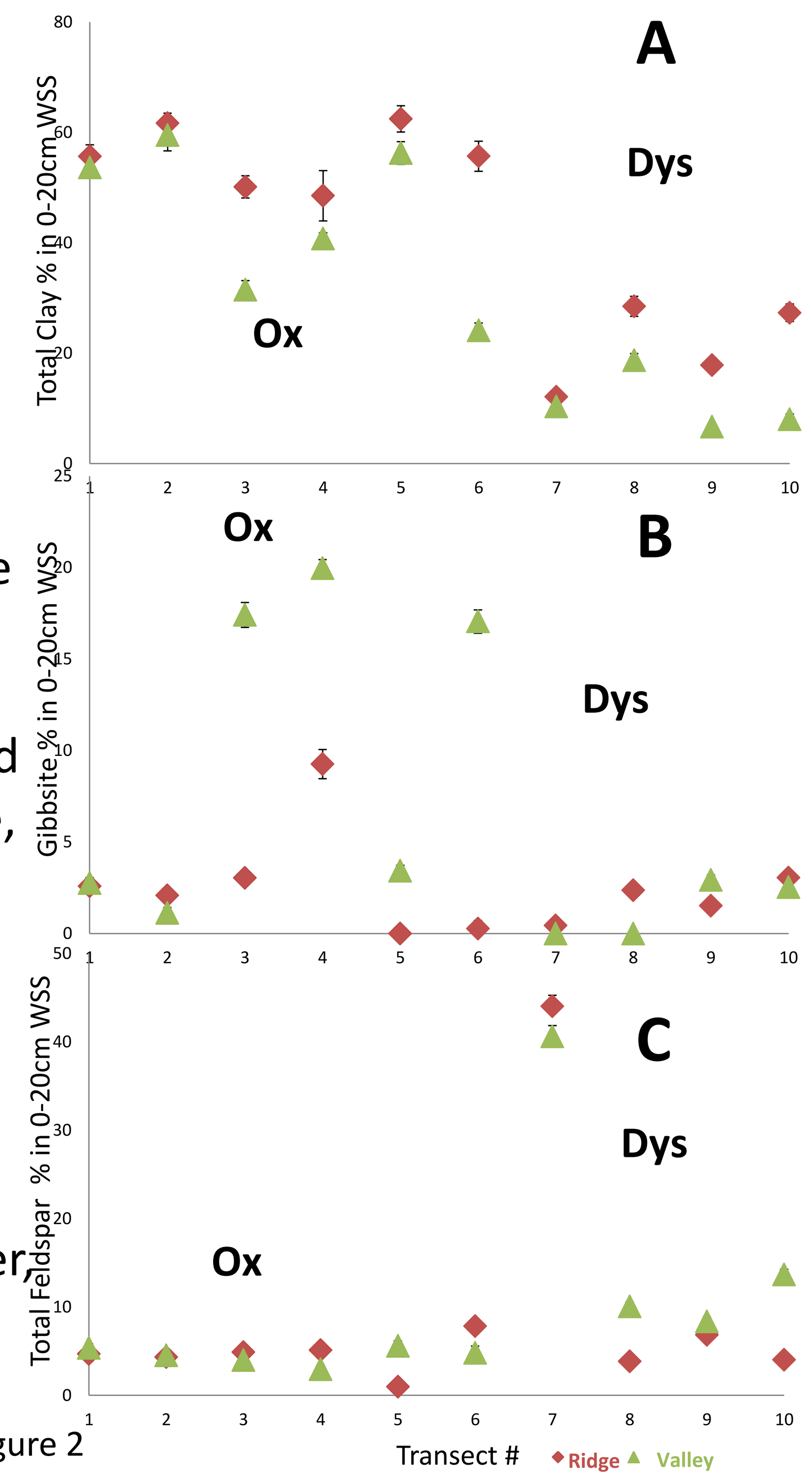

Figure 2

These patterns of the % of total clays, feldspars, and gibbsite within each and between transects, in combination with Equations 1&2, indicate that soil in the valleys are more weathered than soil from ridges which could interpreted as due to the closeness of the valley soils to water table.

All samples studied except #27 contain phosphate minerals (augelite and metacariscite) with the total percentage up to 15%. (Fig. 3)

Whole soil samples from the Oxisols sites have higher concentration of the two phosphate minerals than samples from the Dystrudepts site. Also, the higher the clay content of the sample the higher % of the phosphate minerals. This pattern of phosphate minerals is most probably due to the attachment of the phosphate minerals to clay mineral surfaces.

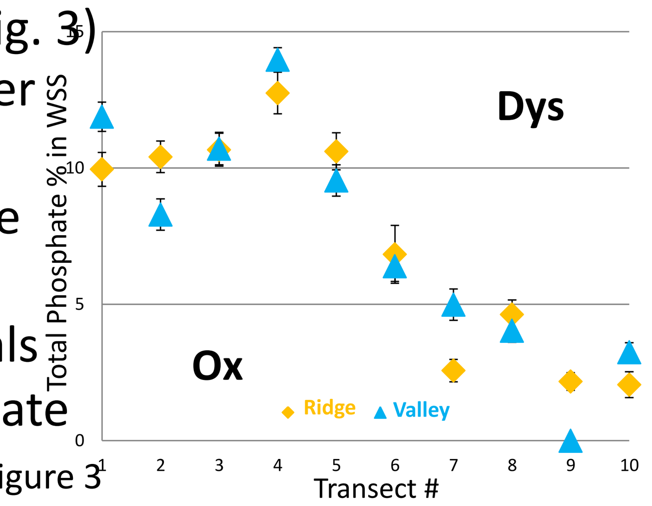

Figure 3

The clay-size fraction of Col Ox 1-4 was treated to remove organic matter and iron oxides. Compared with the untreated sample, the treated sample didn't show the peak at 14° 2θ (Fig. 4). Two minerals， metavarscite (14.05°2θ, intensity 48.8%) and tsaregorodtsevite (13.98°2θ, intensity 60%)， are found to account for the presence of the ~14°2θ.

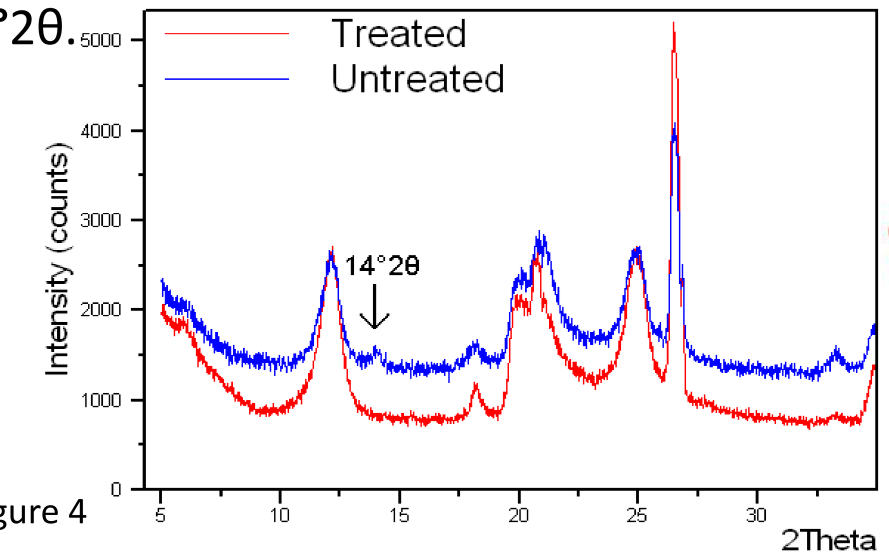

Figure 4

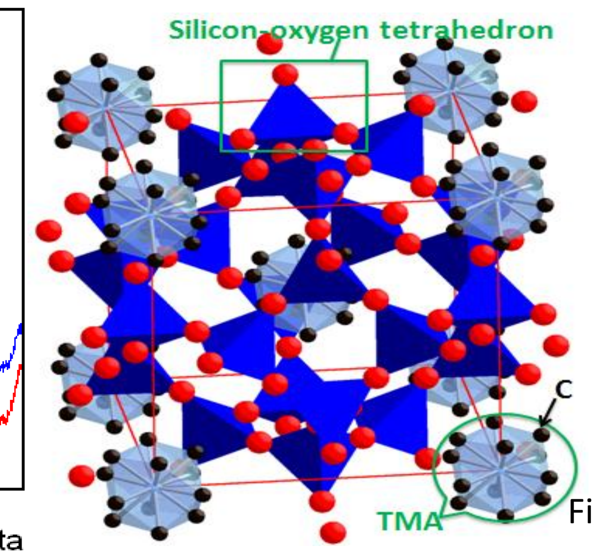

Figure 5

Tsaregorodtsevite($N(CH_3)_4AlSi_5O_{12}$) is listed as a tectosilicate of the feldspathoid mineral group. The nitrogen and carbon ions are present in the mineral in the form of organic cation tetramethylammonium (TMA, $[N(CH_3)_4]^{1+}$). Figure 5 shows that the TMA organic cations occupy the empty channels and cages created by the framework of SiO_4 tetrahedra. This placement is consistent with a low energy mechanism for the sequestration of carbon and nitrogen in tropical soils.

Conclusions

1. Soil sample from Ox (Volcanclastic bedrock) sites contain higher % of clay minerals than the samples from Dys (Quartz-diorite bedrock) sites.
2. The general pattern of the % of total clays, feldspars, and gibbsite within each and between transects indicate that soil in the valleys are more weathered than the soil from ridges which could interpreted as due to the closeness of the valley soils to the water table.
3. Phosphate minerals present in the soil are augelite and metacariscite. The whole soil samples from the Oxisols sites have higher concentration of the two phosphate minerals than the samples from the Dystrudepts sites. This pattern is most probably due to the attachment of the phosphate minerals to clay mineral surfaces.
4. Tsaregorodtsevite was detected in most of the Ox and few Dys samples. The presence of the organic cation tetramethylammonium in the cavities between the oxygen-silicon tetrahedra of the tsaregorodtsevite structure is consistent with a low energy mechanism for the sequestration of carbon and nitrogen in tropical soils. However, the chemical and thermodynamic details of this mechanism need to be worked out by further investigation.

References

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