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Chronosequence of volcanic soils in Garrotxa area (Catalonia, Spain)

O. Palou (1), R.M. Poch (1), J. Boixadera (1,2)

(1) Departament de Medi Ambient i Ciències del Sòl, University of Lleida, Catalonia, Spain.
(2) Secció d'Avaluació de Recursos Agraris, Departament d'Agricultura, Ramaderia i Pesca, Generalitat de Catalunya, Catalonia, Spain.

Neogene vulcanism occupies an area of 3300 ha in the Garrotxa area in Catalonia. Previous studies show the importance and singularity of soils developed on these materials, highlighting the presence of Andisols (SSS, 1994). The objective of this study is to explain the pedogenesis of these volcanic soils developed on rocks of known age.

The area has an elevation ranging from 200 m to 1027 m. The parent material consists of consolidated quaternary effusive rocks as alkaline-basaltic lava and pyroclasts, basaltic lava and basanite lava. All these materials are characterized by a constant geochemical composition (Mallarach, 1984). The volcanic materials date from 11 500 to 250 000 years BP. The volcanic landforms as strombolian cones without crater, breached cones, horseshoe-shaped craters, viscous flows with scoriaceous or rough surfaces and fluid flows with smooth surfaces. The climate is Humid Monainous Mediterranean with an average annual rainfall of 1000 mm, with a short dry period at the end of the summer. The average temperature is 13ºC (19ºC in summer and 4ºC in winter). The moisture and temperature regimes (SSS 1996) are Udic and Mesic, respectively. The forest vegetation covers 60% of the surface, predominantly oak and beech woods. The cultivated area is about 25%, mostly cereals.

Fourty-nine profiles were described, and sampled for physico-chemical and mineralogical analyses. Micromorphological and submicroscopical analyses were done on 8 of the profiles.

There are no clear differences between soils according to their parent material but yes depending on their age. Soils on young volcanic materials (11 500 years) are loamy and coarse loamy, have well-developed structure, bulk density around 800 kg/m^3 and

high moisture retention, which decrease with age.

Electrical conductivity is lower than 0.2 dS/m in the topsoil, and decreases to 0.1 dS/m in subsurface horizons. The pH range is from 5.8 to 6.6 in surface horizons and from 6.3 to 7.5 in depth. The amplitude of pH range decreases in older volcanic materials.

The amount of exchangeable bases is high, particulary in soils on young materials. The ratio of Alp to Alo (Alp/o) ranges from 0.5 to 0.1, and the amount of noncrystalline components had values from 18 to 30% in soils on young materials.

Therefore, the soils on youngest parental materials have andisol properties, except in the cases where they have anthropic characteristics.

X-Ray diffraction revealed the absence of volcanic glass in all soils, being quartz and feldspars the dominant minerals in the sand fraction. Clays consist of kaolinite and chlorite in soils on basaltic lava flow, and smectites in volcanic pyroclastic soils. TEM on selected samples confirmed the presence of allophane and imogolite in andosols. There were not significant mineralogical differences according to the age of parental material.

The micromorphology of the oldest soils ($>$ 200 000 y) shows dominant textural uniform clay coatings and infillings of limpid clay without inclusions of micro-particles, with light yellow colour. They occur in narrow voids and mineral weathered surfaces. Likewise, coatings and infillings of impure clay, containing numerous contrasted particle size of the silt-size, were observed in illuvial B horizons. Clay and silt textural pedofeatures were observed in several soils with agricultural use. Frequent fragments of clay coatings or infillings were observed embedded in the soil matrix, associated to the faunal activity, seismic movements or erosion processes.

The most common forms of ferruginous and manganiferous pedofeatures were depletion and crystalline pedofeatures, as a result of the mobilisation of Fe and Mn components subjected to periodic waterlogging and alternating redox conditions. Newformed clay was observed in the younger soils.

The study of the chronosequence shows that the processes involved in the formation of these Andisols are the accumulation of organic matter and its stabilization by aluminium and iron in surface horizons, formation on thin B horizons by in situ weathering, structure formation, and formation of noncrystalline materials. In a later stage the clays are mobilised and illuviated.

The climate is the principal formation factor in these Andosols, essentially for the presence of a high constant humidity in the soil. In these conditions Andisols keep their andic properties for a long time, without an apparent evolution. The cultivation

of these soils brings about a destruction of the amorphous materials and the evolution to a latter stage of development.

With middle stage of development, soils become deeper, with incipient B horizons, high leaching of bases, allophane destruction by crystallization, basification, organic matter losses and formation of chlorite.

At a latter stages of evolution clay illuviation proceeds. In the area, this process requires about 3000 years.

Soils on young volcanic materials (11 500 years old) are classified as Typic, Lithic and Eutric Hapludands. The soils in their middle stage of development are classified as Typic and Lithic Hapludolls, and Typic Eutrudepts. The oldest soils have an argillic horizon and are classified as Typic Argiudolls and Typic Haploxeralfs. These kind of soils are only described on old volcanic materials (more than 200 000 years old) or on quaternary volcanic deposits.

Therefore, we hipothesize that the formation orders sequence is Entisol - Andisol - Inceptisol - Alfisol. The results suggest a further evolution to a Vertisol, since smectite is present in some samples.