Assessment of temperature peaks reached during a wildfire. An approach using X-ray diffraction and differential thermal analysis

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Introduction

The temperature reached during a wildfire may be rather heterogeneous through the burned area. Temperature peaks depend on several factors such as vegetation type and density. Wildfires may induce important chemical and physical changes in soils, including changes in the soil composition, mineralogical properties, soil water repellency, aggregate stability or texture. As these changes usually occur after known specific threshold temperatures, the study of these variations may help to explain many of the processes occurring during burning and in the post-fire, and these processes might be used as indexes of fire severity.

Objectives

The objective of this research is to study the relation between fire temperature and mineralogical changes induced in soil samples under laboratory conditions, using X-ray diffraction, differential thermal analysis (DTA) and thermogravimetric analysis (TG).

Methods

Topsoil samples (0-5 cm deep) from calcareous soils of Alicante (eastern Spain) were collected for this study. Soil samples were grinded using an agate mortar and then sieved (<0.002 mm) and analyzed by X-ray diffraction (XRD). XRD was conducted on a Bruker (model D8 advance A25) powder θ:θ diffractometer (figure 1), which uses a Cu anticathode (40 KV, 30 mA), Ni filter in the diffracted bean and lineal detector.

Figure 1. Bruker diffractometer used in this study.

Powder samples were scanned from 3 to 70º 2θ, using a step size of 0.015º 2θ and a scan speed of 0.15º 2 s^{-1}. The identification of mineralogical phases and quantification of minerals was carried out with the software pack XPowder.

In order to study other possible reactions in burned soils, soil samples were exposed to temperatures of 300, 500 and 700ºC in a Mufla furnace during 20 minutes. Unheated samples were used as controls. After treatments, both control and treated samples were analyzed by DTA and TG.

Results

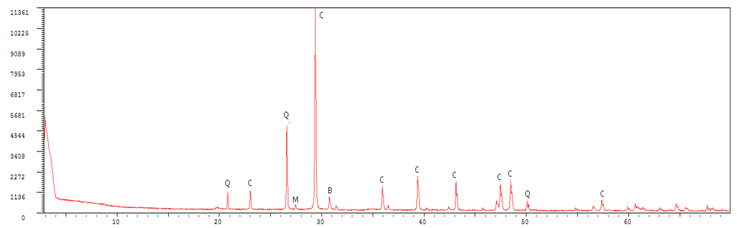

Figure 2. X-Ray diffraction (XRD) analysis of unburnt soil sample. Identification of diferent mineral in the sample. Q (Quartz), C (Calcite), M (Microcline) and B (Blixite)

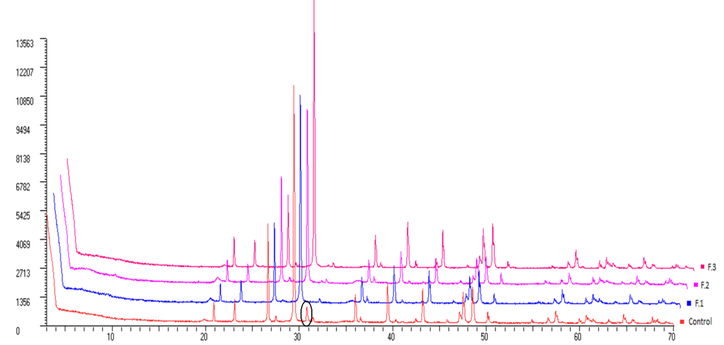

Figure 3. X-Ray diffraction analysis of soil samples heated at 300 (F1), 500 (F2) and 700 ºC (F3), and unheated soil samples (control). The peak associated to blixite is marked.

Table 1. Semiquantitative analysis of soil samples heated at 300, 500 and 700 ºC and unheated soil samples (control).

Sample	Calcite	Quartz	Microcline	Blixite	Amorphous
Control	62.3	26.1	3.8	1.1	6.8
300 ºC	79.0	10.1	2.6	-	8.3
500 ºC	72.6	11.1	5.3	-	11.1
700 ºC	77.4	11.0	5.9	-	5.7

Diffractograms do not show significant variations for 300, 500 and 700 ºC, except in the case of the peak associated to blixita, which is not observed in the diffractograms of heated samples. Peaks associated to other representative mineral substances (calcite, quartz and microcline, for example) do not show significant changes between control and heated samples.

After semiquantitative analysis, the proportion of calcite increased in burnt soil samples (76.3%, on average) respect to control unburnt soil samples (62.3%). This increase may be explained by calcium carbonate released by ash after combustion of organic matter. Consequently, quartz proportion decreased in burnt samples (10.7%, on average) respect to control samples (26.1%).

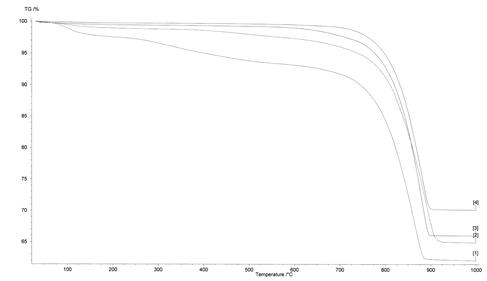

Figure 4. Thermogravimetric analysisof unburnt soil sample and unburnt soil samples exposed to differents temperatures. Unburnt soil sample Line [1], unburnt soil sample exposed to 300ºC Line [2], 500ºC Line [3] and 700ºC Line [4].

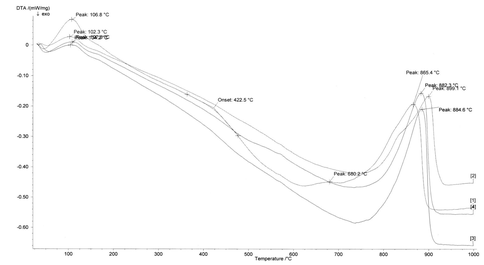

Figure 5. Diffetential thermal analysis of unburnt soil sample and unburnt soil samples exposed to differents temperatures. Unbornt soil sample Line [1], unburnt soil sample exposed to 300ºC Line [2], 500ºC Line [3] and 700ºC Line [4].

After DTA analysis, a valley occurs between 400 and 700ºC in the control sample which is not present in 500 and 700ºC heated samples. This loss of energy is attributed to combustion of organic matter approximately between 400 and 500ºC, as well as thermal changes in iron oxides (which occurs approximately between 300 and 500ºC) and loss of structural water (> 420ºC). In samples heated at 500 and 700ºC, these changes are not appreciated as they occurred during calcination. In the 300ºC heated sample, some of these changes partially occurred. Peaks observed approximately at 100ºC correspond to release of absorbed water. Peaks at 900ºC are a consequence of destruction of calcite. Finally a peak was observed at 680ºC in the control sample may be explained as a consequence of the destruction of blixite ($Pb_8(OH)_2Cl_4$), which was present in control samples (1.1%) but not in burnt samples. This peak is probably masked in heated samples

Acknowledgments

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