INFLUENCE OF AGRICULTURAL BURNING ON MAGNETIC PROPERTIES IN MAYA MILPAS

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ABSTRACT

A detailed rock-magnetic investigation was carried out on the four most common agricultural soils in Pich, Campeche: Lithic Leptosol (LPli), Chromic Stagnosol (STch), Antrosol (AT) y Humic Rendzic Leptosol (LPhurz). These soil samples were heated from 250° C to 650° C using 50° C increments. We used different soil samples by each temperature level. The magnetic properties at each temperature have been measured using a Variable Field Translation Balance. Variation of rock magnetic parameters as a function of temperature allows the determination of the main magnetic minerals (primary and secondary) and their thermomagnetic stability. Changes in magnetism were correlated with temperature, but varied by soil group. It was detected a firm relationship between the magnetic parameters and temperature by each soil group.

Keywords: agricultural soils, Campeche, magnetic parameters

INTRODUCTION

The magnetic characteristics of soils are widely used in environmental and paleoclimatic investigations as proxies for factors that are more difficult to study directly. Magnetic parameters are easily, rapidly, and inexpensively determined providing a highly sensitive measurement of the compositional changes of minerals in the soil. Moreover, the measurements of soil magnetic properties provide information about the developmental history of the soil and thus may be used to investigate environmental change and pedogenesis.

Maya soil management techniques considered traditional in this area include controlled burning on a rotation that includes two (or three) years of cropping and a forest management cycle of twenty years or more. The use of fire in agriculture is controversial; positions in favor of the use of fire are based on increasing soil fertility due to ash phosphorus inputs. The positions against the use of fire argue based on nutrient loss by burning, loss of organic matter and soil degradation. However, no published archeological research as yet reports evidence of milpas (cornfield) with a twenty-year fallow cycle, which we have found to be considered ideal in Pich (Faust and Bilsborrow 2000). Such practices have to be inferred as they do not involve modifications of the landscape.

The aim of this work was the identification of magnetic and mineralogical changes in soils due to the application of heat under controlled conditions

LABORATORY PROCEDURES AND RESULTS

This study of long-fallow (or shifting) agriculture was done in Pich, Campeche, Mexico and a neighboring private ranch, Rancho Cauich, located approximately 4 km to the south of town. The center of Pich is 85 km by highway to the southeast of the state capitol, San Francisco de Campeche, a coastal city encountered by the Spaniards in 1519. The geographical coordinates at the center of Pich are 19° 29' 05'' latitude and 90° 07' 06'' longitude with an altitude of 110 to 140 meters above sea level.

We sampled four different Maya soil classes identified as preferred soils by traditional Maya farmers of Pich, Campeche in unburned areas adjacent to their burned fields. Fractions of each sampled soil class were burned for 30 minutes (fig. 1) in a furnace (model Thermolyne 1400° C) in the laboratory at a temperature between 250 and 650° C with increments of 50° C.

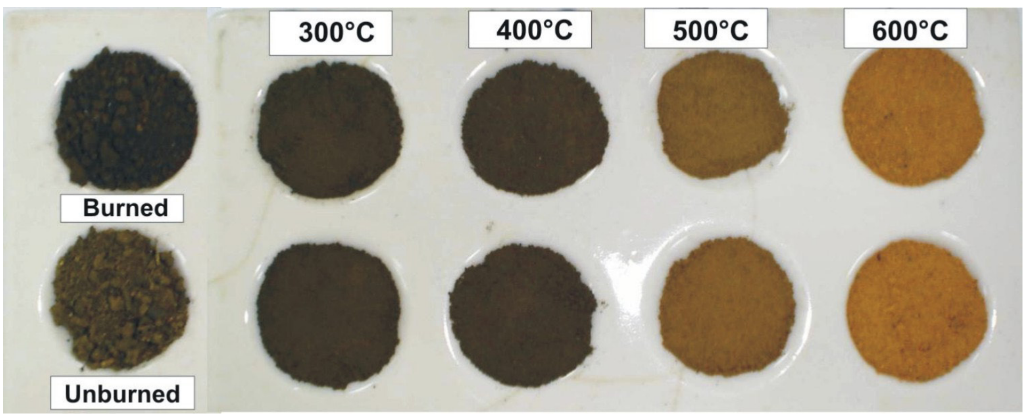

Figure 1. An example of Campeche soil sample (Stagnosol) burned at different temperature under laboratory conditions.

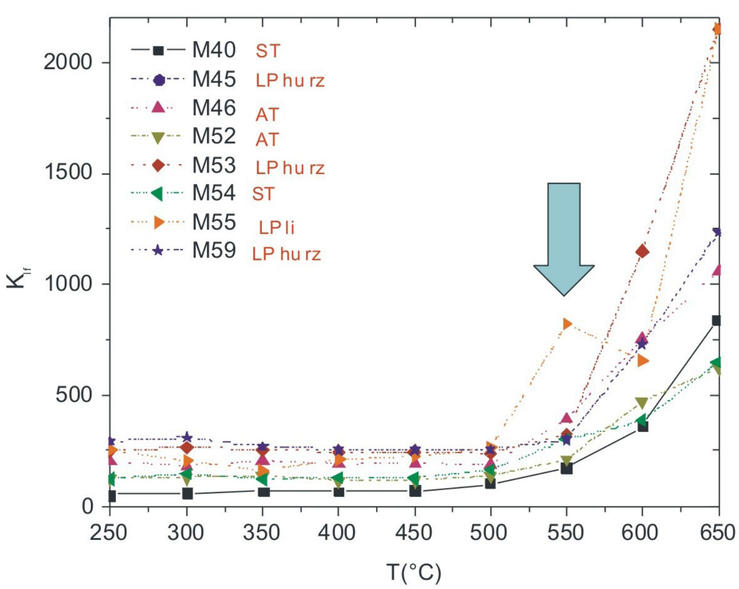

Figure 2. Variation of bulk magnetic susceptibility *vs.* temperature for all studied soil samples.

As an initial step before performing the laboratory experiment, the low-field magnetic susceptibility (MS) was measured on each sample with a MFK-1 (AGICO, noise level ~ 3 x 10^{-8} S.I.) kappabridge (fig. 2) at each temperature steps. A series of rock-magnetic experiments with a Magnetic Field Translation Balance (MM_MFTB) were performed. These included the measurement of progressive isothermal remanent magnetisation (IRM) acquisition curves, hysteresis loops (± 1 T), backfield coercivity curves and thermomagnetic curves up to 700° C in air. Heating and cooling rates of thermomagnetic experiments were 10 - 15° C min^{-1} applying a field of 38 mT. Curie temperatures of Js-T curves were calculated using the two-tangent method (Grommé *et al.*, 1966). Saturation magnetization (M_s), remanence saturation magnetisation (M_{rs}) and coercive field (B_c) were calculated from hysteresis loops after subtracting the dia/paramagnetic contribution. These parameters combined with the coercivity of remanence (B_{cr}) determined from the backfield curves, were used to estimate the domain state distribution of the studied. All these experiments were carried out at the Laboratory of Palaeomagnetism of Burgos University (Spain).

The bulk susceptibility variation with temperature remains essentially stable and unaltered until 500° C (fig. 2). Beginning from 550° C an abrupt changes are observed reaching its maximum at 650° C. This phenomenon is probably due to the production of neo-formed magnetite grains during consecutive heatings.

Figure 3 illustrates the thermomagnetic curves and respective hysteresis loops corresponding to samples from soil M40 (Stagnosol). The main magnetic carrier is magnetite perhaps a magnetite with no significant isomorphous substitution, although some phases or mineralogical alterations at low-intermedium temperatures (< 450º C) can be distinguished. Around 250º C a slight increase in the heating curve is observed, indicating a magnetic phase or more probably a mineralogical transformation induced by heating. Interestingly, this phase or mineralogical transformation is also visible in samples heated at higher temperatures. It should be noted that this change has also been observed in the other soil-types so additional experiments are being performed in order to identify it.

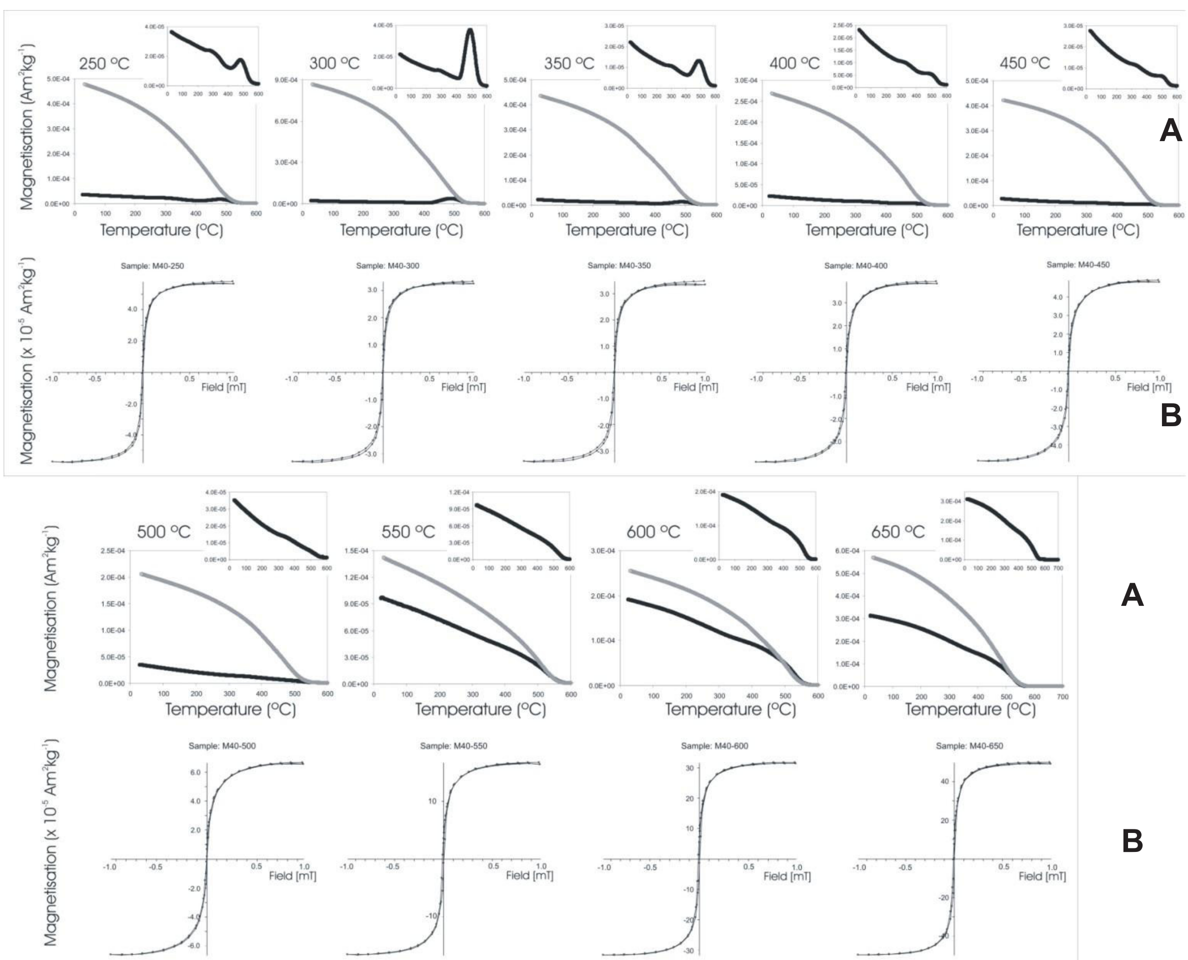

Figure 3. **A**: Thermomagnetic curves corresponding to Stagnosol samples. Temperature shown in the insets indicates the original heating temperature underwent by that sample. Heating and cooling curves are denoted in black and grey, respectively. Only heating curves are plotted in the insets for clarity. **B**: Hysteresis cycles corresponding to each thermomagnetic curve.

Samples heated at the lowest temperatures display a clear magnetization increase around 400º C indicating the creation of additional magnetite during laboratory heating. As expected, magnetic transformations are attenuated at higher temperatures. Likewise, the intensity of magnetisation of thermomagnetic curves progressively increases in those samples originally heated at high temperatures. The formation of secondary magnetite in the samples originally heated at high temperatures is less than those heated at lower temperatures (in relative terms) as denoted by the cooling curves. However, these thermomagnetic curves are not reversible. All hysteresis cycles are dominated by a pseudo-single domain (PSD) low-coercivity mineral, showing also an increase in the magnetisation of the samples heated at the highest temperatures. The intensity of the magnetic changes depends on the soil group.

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