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PRELIMINARY CLIMATIC INTERPRETATION OF SEDIMENTOLOGIC AND ROCKMAGNETIC DATA FROM THE CAVE PESTERA CU OASE (SOUTHERN CARPATHIANS, ROMANIA)

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Introduction

In this study we report the results obtained from a cave situated in the western part of the Southern Carpathians (Romania). The cave became famous following the discovery of the oldest modern human of the European continent (40500 cal. years BP, Trinkaus et al., 2003) and of a rich deposit of cave bear bones. The cave was used by bears for at least 4000 years around 43000 years BP (Quilés et al., in press).

A large shaft of the cave was filled almost completely with underground stream sediments in the beginning and uniform to laminated lake sediments in the final stages. Later on, the shaft was partially reopened and the sedimentary sequence exposed. We trenched and sampled in detail 9m of this sequence for sedimentological and magnetic analyses. To identify climatic oscillations in our sequence, we compared magnetic and sedimentological data, examined the magnetic mineralogy in detail, and measured bulk sediment particle-size distributions. The very close correspondence between magnetic properties and paleoenvironmental indicators may result from one or more factors. Possible factors include detrital dilution of magnetic signals, diagenetic alteration of iron-oxide minerals, authigenesis of new magnetic minerals, and climatically-controlled catchment processes of weathering and sediment transport.

The upper age of the sediment is constrained by the age of a stalagmite taken from the surface of the clay deposit. Two exploratory ^{230}Th dates were performed by alpha-spectrometry at the U-series laboratory, University of Bergen, Norway. The two ages are (16.4 ± 1.3) ka and (16.0 ± 1.7) ka. The next time control is provided by the presence of bear bones only in one of the coarse layers situated in the middle part of the section (between 5.2 – 7.2 m depth). This implies that at least the upper part of the section was deposited during marine isotope stages 2 and 3.

Sedimentological data

Trench logging provided information about sedimentary structures, rough grain-size distribution through the sediment column, colors and composition of the sediment (Figure 1). The upper 2 m are composed of dark red laminated clays and silts. Lamination is generally parallel but some wavy laminations also occur. The following 1.5m consists of massive red clays resting on 1 m breccia with 60% red clay matrix. Clast composition in the breccia unit is dominated by limestone and subordinate clay pebbles; upper limit is sharp while base limit was affected by differential compaction suggesting a mudflow unit. Half meter of massive red clays separates the upper breccia unit from a lower one. The second breccia unit (2 m thick) is densely packed, with less than 40% clayey matrix and composed only of limestone and bone fragments. This could be a debris flow unit washed from the upper levels of the cave where bone deposits have been found. The next 1 m is a massive clay deposit containing scarce limestone clasts. The last 1 m is composed of stratified sands draped by thin silt units. Everything is resting on coarse grained terrace deposits with various allochtonous clasts.

In laboratory we analyzed calcimetry, organic matter, and grain-size distribution across sediments from the shaft. Calcimetry was determined by volumetric method measuring the CO_2 resulted from the reaction of dried samples with 4M HCl using the Eijkelkamp calcimeter. Loss on ignition after 6 hours at 550°C was used to quantify the organic matter. Almost all samples collected have been analyzed for calcimetry and organic matter.

Calcimetry values are quite different throughout the section with very low values (around 0.1%) in the upper 4m and high values (around 10%) downward (Figure 1). This difference is mainly given by the limestone pebbles content and not by climatic control on the fluid saturation. The persistence of low values over the entire fine grained deposit of the section could indicate the provenance of silty-clayey material from paleosoils or carbonate-free source material. This sediment could only be brought to the area around cave by winds or surface streams since it could not have formed solely from the weathering of the underlying limestone bedrock. However, such a continuous delivery of fine grained sediment to the cave needs a storage reservoir of the primary detritus, something like a slackwater pool. If the parental material contained some iron sulfides then their oxidation in a pool would have generate strong acid environment capable to dissolve any carbonate mineral and so delivering to the cave a carbonate-free fine grained material.

The organic matter has a reversed pattern in comparison to calcimetry: with high values in the upper 4m and low values downwards (Figure 1). It is a good correlation between the lamination structure which is only present in the upper 2 m of the analyzed sequence and the oscillating values of the organic matter. This aspect could reflect periodic input of organic matter from outside the cave together with coarser grains and mica which gives the lamination structure. When the sedimentary structure becomes massive the values are less oscillating. Generally, the organic matter content is rather high even when low relative values they reach 5%, while the highest values are around 15%. These high values are located just over the mudflow unit at about 3.5-3.7 m counted from top of section. Such anomalous high values for organic matter are hard to explain by pedogenesis solely. North of the cave, upstream along Ponor valley, Paleozoic organic rich sedimentary deposits crop out. They are composed of bituminous shales, siltites and sandstones with coal layers intercalated. It is highly possible that much of the organic matter from cave sediments is derived from Paleozoic rocks.

The entire sedimentary section is dominated by clays; even the breccia intervals have large amount of clay as matrix. Therefore, we performed grain-size analyses using hydrometric method in settling tubes dipped into a thermostatic bath. Samples have been passed through 2 mm mesh sieve, then cleaned for organic matter with peroxide and for authigenic carbonates with acetic acid, rinsed, dried and finally brought into suspension using a polyphosphate solution. Due to time-consuming procedure, both for sample preparation and for analyzes, the grain-size analyze was performed on selected samples.

One particular aspect of the grain-size distribution across the studied section is the arenite content: from top till 5.5 m there is practically no arenite fraction, after this level there is a jump towards coarse grained fraction. It seems that arenite and also silt content doesn't contain any climatic control (Figure 1). More sensitive to climatic changes is the clay fraction, revealing some fluctuation in the upper part of the section. However in the studied section granulometry is not a climatic proxy itself only in correlation with other parameters like magnetic susceptibility. The fine grained sediment from the upper part of the sequence indicates that the shaft was almost completely filled with sediment deposited under quiet pool conditions derived from a filtered source, not from a direct stream.

Rockmagnetic data

Magnetic properties reflect the types, amounts, and magnetic grain sizes of magnetic minerals in geological materials. For the sediments sampled in this study, we measured several rockmagnetic parameters: magnetic susceptibility (MS), anhysteretic remanent magnetization (ARM), and isothermal remanent magnetization (IRM). Of the three magnetic parameters MS, IRM and ARM, susceptibility showed the least dependence on grain size (Peters and Dekkers, 2003). Susceptibility is therefore, perhaps, the best parameter for assessing magnetic concentration in environmental samples. For magnetite, both IRM and ARM decrease with increasing grain size so that large multi-domain grains contribute relatively little in comparison to smaller grains. IRM has no variation with grain size for high coercivities minerals (hematite and goethite). In comparison to IRM, ARM varies more strongly for very small grains (<1 μm) with ARM being particularly strong for magnetite grains with diameters on the order of 0.1 μm to 0.02 μm. Magnetic susceptibility (MS) and its frequency dependence were measured using a MS2B Bartington system. ARM and IRM were measured with JR5 spinner magnetometer. ARM was imparted using an alternating field with a peak intensity of 100 mT and a bias field of 0.05 mT. After measurement of ARM, IRM was first imparted in a 2T field (SIRM) and then in the opposite direction in a field of 0.3 T (IRM0.3T). The ratio, IRM0.3T/SIRM thus is a measure of the proportion of magnetite to all magnetic iron oxides. When values of this ratio,

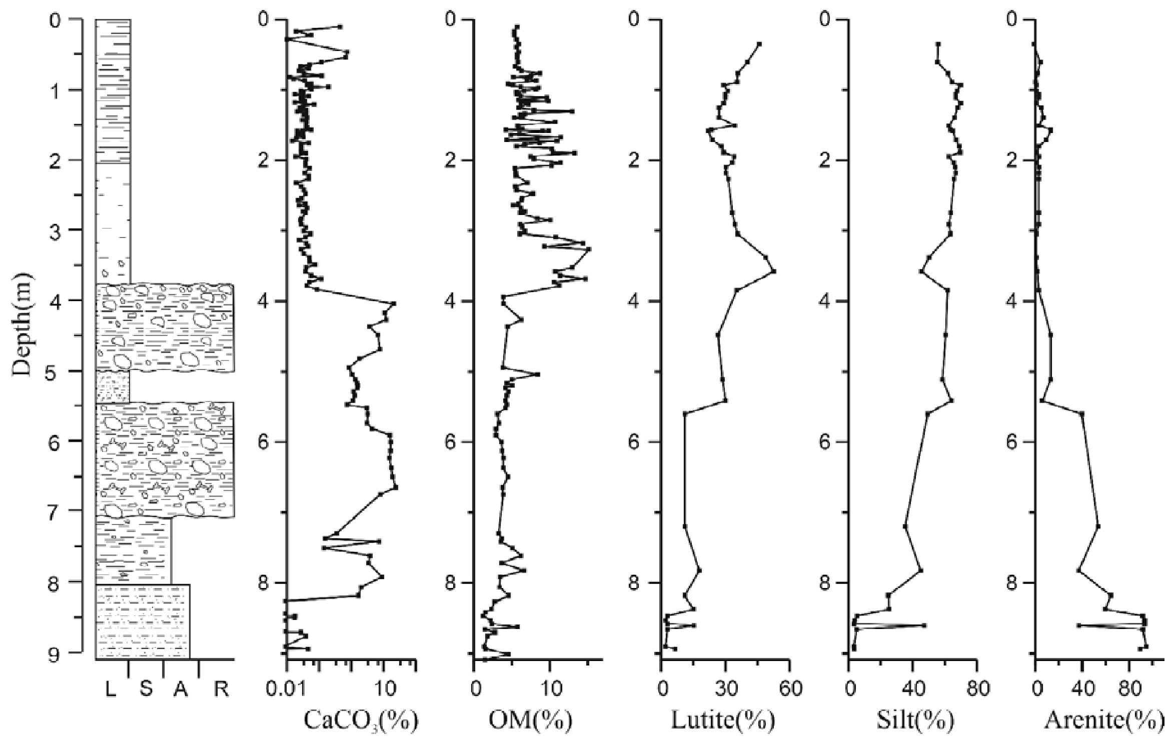

Figure 1. Log of the studied sedimentary section and sedimentologic data. Legend: L=lutite, S=silt, A=arenite, R=rudite, $CaCO_3$=calcimetry, OM=organic matter.

called the S parameter, are high, the iron oxide population is dominated by magnetite (a maximum value of 1); decreasing values indicate increasing proportions of hematite.

Main rockmagnetic results are presented in Figure 2. According to the variation of the S parameter, magnetic mineralogy is dominated by high coercivity minerals. Analysis of IRM acquisition and demagnetization curves on selected samples shows that the high coercivity mineral is hematite. High concentration of hematite characterized the first 3 m from the top of the outcrop. The rest of the section shows several pulses of low coercivity minerals (magnetite and/or maghemite). These changes in magnetic mineralogy are well reflected in concentration dependent parameters (MS, ARM and IRM). Concentration dependent parameters show little variation on the first 2.3 m. The rest of the section is characterized by three peaks of these parameters. The MS variations are in close correspondence with ARM, S parameter and frequency dependence of MS variations. This indicates that MS oscillations are mainly controlled by an input of fine magnetite grains of pedogenetic origin.

The presence of hematite identified through rockmagnetic analyses is correlating well with the dark red color of the fine-grained sediment. Hematite's source could be again the Paleozoic rocks cropping out north of cave. These rocks doesn't contain themselves hematite but they contain lot of iron sulfides, which were oxidized in still-water conditions. All the sedimentological parameters from the upper half of the studied section require the existence of a slackwater pool before the cave insurgence. This pool acted as a filtering system for the fine grained sediment, as an oxidizing environment for the iron sulfides and in the same time as an acidic pool which removed any carbonate mineral from the sediment.

Climatic interpretation of the results

From all studied parameters the best proxy for climatic oscillations seems to be the variation of rockmagnetic parameters produced by the enhanced input of pedogenetic magnetite. Following the interpretation of magnetic susceptibility variations in cave sediments of Ellwood et al. (2001), we have identified three warm periods when the magnetic signal is enhanced due to magnetically enriched soil washed, and entrapped inside the cave (Figure 2). These warm periods are associated with massive clay deposits. They are separated by two cold periods characterized by lower values for MS which correspond to the two breccia units. Fallen blocks are often connected to colder climate when taw-freeze cycles are more frequent (Courty, 1989) and can trigger mudflows and debris flows, therefore we tentatively associate the breccia units to cold periods.

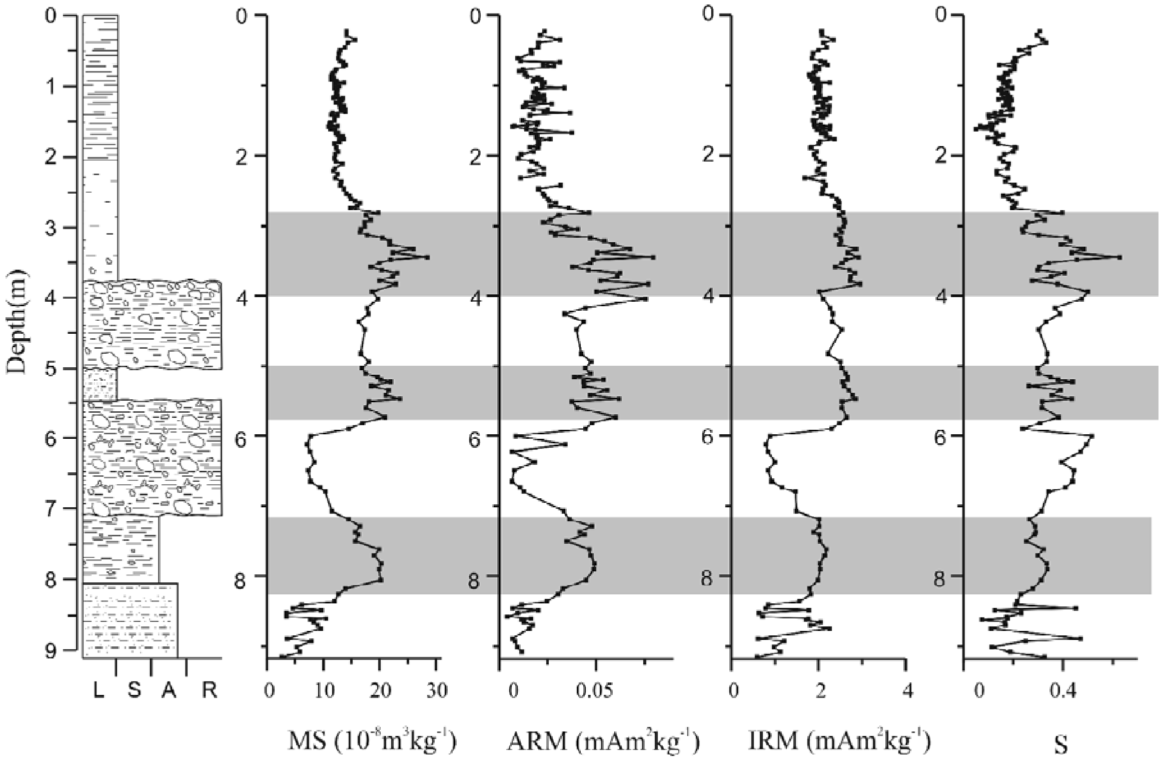

Figure 2. Depth plots of magnetic properties: MS, magnetic susceptibility, ARM, anhysteretic magnetization, IRM, isothermal magnetization, S parameter. Warm intervals are marked with grey boxes.

The results correlate well with the response of Central European vegetation to rapid climate change during isotope stage 3 which shows several interstades with favorable climatic conditions separated by cold stadials (Ellwood et al., 2001; Müller et al., 2003). The upper part of the section dominated by high coercivity minerals and with little variation of magnetic susceptibility was deposited during the Late Glacial Maximum.

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