as a reliable tool for studying the mechanisms of formation and precise timing of glaciations.

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The Magneto-Susceptibility Event and Cyclostratigraphy (MSEC) Method Used for Paleoclimate Estimates and Correlations at Archaeological Sites in Europe: Results for the Middle to Upper Paleolithic

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Over the last 20 years, MS measurements of sediments have been used in paleoclimatic studies of loess (summarized by Heller and Evans, 1995) and as a paleoclimate proxy in marine limestones and shales (for example, Crick et al., 1997; Ellwood et al., 1999). In unconsolidated samples like those excavated from archaeological sites, MS works as a proxy for climate because climate controls the magnetic properties of deposited sediments, primarily as the result of pedogenesis (see Mullins, 1977, for an early summary). The result is higher production of magnetic minerals such as maghemite, magnetite, hematite, or possibly ferrimagnetic sulfides (Stanjek et al., 1994; Ellwood et al., 1997) in soils and corresponding increases in MS during periods when climate is relatively warm, assuming that moisture is available for pedogenesis. Work by Tite and Linington (1975) and Singer and Fine (1989) showed that climate (both temperature and moisture) can have a significant effect on the MS, and that in general, warmer/wetter conditions enhanced the MS signature during pedogenesis. Besides maghemite, Maher and Taylor (1989) have shown that magnetite is readily produced during soil formation. (Much of the work concerning the production of ferrimagnetic minerals in soils has been summarized by Fassbinder et al., 1990).

For paleoclimate studies, MS, independent of other measurements, has been shown to be very sensitive to subtle changes in total iron concentration of sediments (Banerjee, 1996). Thus, the addition to sediments of maghemite or magnetite increases the MS. Furthermore, the authigenic production of maghemite produced by pedogenesis appears to be relatively stable chemically (Mullins, 1977), resulting in a stable MS signature that is preserved in sediments.

Soils that are formed through pedogenesis outside caves and shelters, along with their magnetic constituents, are eroded and deposited within caves or deep rock shelters by wind, water and other processes. This produces a signature of climate that potentially can be identified by measuring the MS. One test of this model is an evaluation of the within-site MS correlation power. After performing such tests at a number of open air and cave sites, we believe it is clear that excavation units from the same locality can be correlated using MS variations (Ellwood et al., 1994, 1995, 1996, 1997). At these sites, smallscale diagenetic effects, local disturbances, or other within-site disruptions were not sufficiently extensive to destroy the correlation power of the curves produced.

We have now shown clear climatic correlations to the Last Glacial Maximum in Portugal (Ellwood et al., 1998) and to independently published climate trends such as established glacial advances and retreats, pollen and other indicators (Denton and Karlén, 1973; Ellwood et al., 1996, 1997, 1998; Watts et al., 2000). In addition, we have demonstrated the presence of a known 2500 year neoglacial climate cyclicity (summarized by Mitchell, 1976) in Konispol Cave samples (Ellwood et al., 1997). This neoglacial cyclicity is independently observed in the Greenland GISP2 ice core (O' Brian et al., 1995). Our previous work has also shown that extremely fine-grained (< 0.1µm) soil-formed maghemite is the dominant magnetic constituent responsible for the MS we observe (for example, Ellwood et al., 1998).

Of course, there are sediments in which problems exist that make correlation or paleoclimate estimation difficult or impossible. However, many of these problems can be avoided by careful, high-density, continuous sampling, treatments to samples before measurement (such as separation of the fine fraction of sediment by sieving), and careful evaluation of the sedimentary sections being sampled. For example, it is often possible in excavation surfaces to identify zones of sediment non-deposition or erosion, and these zones can then be taken into account during final analysis. It has been argued that some cave-derived or other non-climate related material is responsible for the observed MS. However, most of these constituents in cave sediments are relatively coarse-grained. To reduce this problem, we first measure the MS for the field-collected sample, and then we sieve the sample and collect the < 1 mm fraction, for which the MS is also measured. It is the post-sieving MS value that we now use in the final presentation of results, but we also compare it in the laboratory with the initial MS values to evaluate differences. With a few exceptions these differences are usually slight.

We report here the magneto-susceptibility event and cyclostratigraphy (MSEC) method applied to the problem of archaeological site correlations and paleoclimate estimation at sites across southern Europe. This work includes results from sites located in Portugal, north central, NE and SE Spain, south central France, Belgium and Albania. The method makes it possible to resolve some age ambiguities within and between archaeological sites in the region and to estimate relative paleoclimate at these sites. MSEC involves building a regional composite reference section (CRS) from samples at archaeological sites from which isotopic dates, faunal information or cultural affinities are available, and for which the magnetic susceptibility (MS) has been measured. The MSEC CRS then serves as a standard to which MSEC data from other excavations can be compared.

The MSEC method for correlation between cave sites is based on the fact that regional, long-term climate cycles control, through pedogenesis, the magnetic material being created in the region. Sampling for MSEC in conjunction with archaeological excavations provides data sets tied directly to excavation levels, isotopic dates and cultural associations. Because MS variations appear to be controlled primarily by climate, and because the effects of climate are regional, affecting large areas, MS trends identified at one site or in one excavation unit appear at many sites/units within the region. These trends may be modified locally, but in general the variations in MS trends and magnitudes produced by changing climate provide stratigraphic sequences that can be correlated between excavation units that overlap in age. Correlated profiles are used here to develop a CRS of profiles that in turn represent all the MS variations within an area (e.g. Ellwood et al., 1996, 1997). This CRS can be used for correlation or to estimate paleoclimate. Thus MSEC has the potential to become another independent methodology, alongside conventional methods such as sedimentology and palynology, that can be used to correlate within and between sites by tracing paleoclimatic change. MSEC avoids many drawbacks of other methods, such as high sensitivity to diagenetic changes, poor pollen preservation in caves, ambiguous isotopic ages and the need to acquire oriented or very large samples (MSEC can be performed on 2–10 gm samples).

In order to make a direct comparison between the caves thus far collected, and to establish time lines between the caves, we use the graphic correlation method (see Shaw, 1964). We began the compositing process with the construction of time/depth/MSEC graphs based on radiocarbon dates in Upper Pleistocene and Holocene sediments from Konispol Cave Albania, El Mirón Cave, Spain, and Picareiro Cave, Portugal. From these graphs, equivalent time points allowed us to build a CRS for the last ~ 20,000 years. We then added additional caves in Portugal and Spain, and a pollen record from a lake core in Italy, where dates were available, to extend the CRS back to 40,000 years. In addition we present here an extension of the MSEC CRS back into the Middle Paleolithic using data from caves in south central France, SE Spain, and Belgium.

The MSEC intervals represented in the MSEC CRS are interpreted to reflect climatic trends, warmer/wetter during times represented by hatched MSEC zones, versus cooler/dryer climates equivalent to open zones in the MSEC CRS. Because MSEC reflects climatic changes, these data can be correlated directly to the SPECMAP oxygen isotopic curve which provides a robust test of the method. New MSEC results acquired from individual excavated sections can be applied directly to the MSEC CRS and used either as a relative dating tool, for correlation between sites or for paleoclimatic analysis. However, such comparisons require high-density data sets and some isotopic, cultural or biostratigraphic control. The method also allows missing MSEC intervals from one site to be picked up and identified in others.

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Palynological Studies from the Ochozská Cave and from the Šošůvka Part of the Sloupsko-Šošůvská Cave (Moravian Karst)

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ABSTRACT. From the Ochozská Cave the samples from the two profiles were studied. The lower parts of the profiles contained representants of the heliophilous cold steppes (Helianthemum, Thalictrum, Selaginella selaginoides, Ephedra), cold resistent wood plants (Pinus, Betula, Salix) and hydrophilous plants and alges (Cyperaceae, Botryococcus, Pediastrum). These belong most likely to the one cold phase of the Late Glacial. In the upper part of the profiles high amounts of the genus Tilia and of the family Polypodiaceae were found. This accumulation was probably caused by special conditions during the sedimentation and it is probably of the Early Holocene age.

From the Šošůvka Cave individual samples were studied. They contained above all the steppe elements (Thalictrum, Galium, Centaurea, Asteraceae, Ranunculaceae, Daucaceae, Poaceae) and a small amount of the trees pollen (Pinus silvestris, P. cembra, Betula, Tilia, Alnus). Some samples contain cold elements (Selaginella selaginoides, Botrychium), other warmer ones (Teucrium, Scabiosa). Their ages are still not determinated.

The sediments from the Kůlna cave are dated archeologically. Their palynospectra are similar to the inner part of the Šošůvka cave and they may be used for comparison with the above mentioned ones.

KEY WORDS: Moravian Karst, palynology, Pleistocene - Holocene.

Cave sediments from the Moravian Karst were not intensively studied from the palynological point of view. Only Svobodová (1988,1992), Svobodová in Seitl et al. (1986) and Svobodová in Svoboda (1991) studied these sediments sofar.

My studies were made in the sediments of the caves Ochozská (the southern part of the Moravian Karst), Kůlna and Šošůvka part of the Sloup-Šošůvka caves (northern part of the Moravian Karst). Palynological studies were made in the collaboration with further geological and archeological disciplines.

Alltogether 52 samples were examined by palynological maceration. The samples from the Ochozská and Kůlna caves