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Fluorescence microscopy of pollen and spores: a tool for investigating environmental change

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Abstract

Fluorescence microscopy of fossil pollen and spores has only been exploited by palynologists for geological time scales. A reconstruction of ecological change, blanket peat erosion and consequent sediment flux within an area of moorland in the north of England during the late Holocene has provided an opportunity to evaluate whether fluorescence microscopy of pollen and spores can be used as a tool for reconstructing environmental change at shorter and more recent timescales.

The fluorescence properties of pollen and spores in samples of blanket peat (sediment source) and reservoir sediments (sediment sink) were assessed during routine pollen counts. Fluorescence varied with taxon. Bog surface processes such as moorland fire and dessication were observed to have no visible effect on fluorescence, but air pollution deposition (indicated by Pb) did have an effect, although exactly which pollutant(s) is responsible is unclear.

The effect on fluorescence of the physical processes associated with peat erosion and re-sedimentation in reservoirs was examined. Spores of lower plants found in reservoir sediment samples with a high content of eroded peat were well preserved (fluorescing at blue-green wavelengths), suggesting that the eroded peat was transported from the bog surface to the reservoir as peat fragments containing pollen and spores. There is a direct correlation between the proportions of pollen and spores with extinguished fluorescence (very poor preservation state) in sediment samples, and sediment accumulation rate. This relationship is probably not applicable for quantitatively estimating sedimentation rate at other sites due to the effect of local factors. However, the relationship can provide the basis for a simple, quick and relatively inexpensive method of examining qualitative shifts in sediment flux, which can be conducted during routine pollen counts.

Keywords: fluorescence microscopy; Holocene; pollen; sedimentation; peat erosion; Pennines

1. Introduction

The sporopollenin portion of a fossilised pollen or spore contains compounds that have been

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termed 'fluorophors' and 'chromophors' by Lin and Davis (1988). These compounds contain specific types of heteroatomic carbon bonds, and give sporopollenin the property of autofluorescence—the emission of light (or other radiation) from a substance when bombarded by radiation of shorter wavelength.

The wavelength of the emitted light ranges in wavelength from 400 nm (blue) to 700 nm (red), with a distinct peak, and is related both to plant species and to the state of preservation of the palynomorph (van Gijzel, 1971). Less resistant sporopollenin compounds are responsible for shorter blue-green wavelengths, whilst resistant compounds fluoresce at longer orange-red wavelengths. The effect of several environmental factors and processes on fluorescence and sporopollenin content and structure has been demonstrated for: burial in sediments (Batten, 1991); cryoturbation (van Gijzel, 1971); soil type and pH (Havinga, 1971); tropospheric ozone pollution (Roshchina and Karnaukhov, 1999; Roshchina and Mel'nikova, 2001).

The exploitation of fluorescence microscopy as an investigative tool by palynologists has so far been restricted to studies on geological time scales. Over time, buried fossil pollen and spores experience extreme temperatures and pressures. The less resistant components of sporopollenin will degrade, precipitating a shift in fluorescence colour from blue-green to red, and eventually the total extinction of fluorescence. This phenomenon has been exploited in the past to provide rough age determinations of deposits (van Gijzel, 1967), and the presence of reworked sediments (Traverse, 1988; Phillips, 1972; Waterhouse, 1998). Diagenesis (oxidation) of the exine in surface sediments will produce a similar effect on preservation state and fluorescence (i.e., a decrease in fluorescence intensity and shift towards red colours) to that of burial over geological time scales, albeit through a different process. The relationship between the fluorescence of fossilised pollen and spores and other organic matter with hydrocarbon potential has also led to fluorescence microscopy being used to assess the proportion of highly oil-prone constituents in deposits (e.g., Tyson, 1995).

A reconstruction of environmental processes and factors occurring on an area of moorland in the north of England during the Holocene period (last 11 500 cal. years) has provided an opportunity to evaluate whether fluorescence microscopy of pollen and spores can be used as a tool for reconstructing environmental change at shorter and more recent timescales. The catchment of March Haigh reservoir lies in the Pennine Hills between Manchester and Leeds (Fig. 1). A multi-proxy study by Yeloff (2002) examined the erosion of the predominantly blanket peat-covered catchment, and the consequent deposition of eroded peat into the reservoir, which acts as a sediment sink within the catchment. Analyses of blanket peat and reservoir sediment stratigraphies have produced a 160-year record, from 1840 AD, of ecological change, peat erosion and reservoir sedimentation for the area. Analyses of peat and reservoir sediments dated using ^{210}Pb and ^{137}Cs have distinguished three major significant environmental changes since 1840: (1) the disappearance of *Sphagnum* spp. in the mid 19th century, from the effects of air pollution and/or climate; (2) the replacement of *Calluna vulgaris* by graminoid species as the dominant vegetation type, caused by severe fire(s) during the period 1918–1930; (3) a reduction in the vegetation cover of the catchment, caused by severe fire in the summer of 1959. High sheep stocking levels after the 1959 fires maintained areas of bare peat exposed by fire, and initiated erosion. This resulted in large volumes of eroded peat being deposited in the reservoir from 1963 to 1999, with a significant peak occurring from 1976 to 1984.

This provides the opportunity to examine the effects of a number of environmental factors and processes on the fluorescence of pollen and spores of various plant species, by testing several hypotheses: (1) fluorescence characteristics will vary with taxon; (2) the physical processes associated with erosion and re-sedimentation of peats in the reservoir will result in an increased deterioration of pollen held within the reworked deposits; (3) heating and thermal maturation of pollen subjected to moorland fire will result in increased deterioration; (4) deposition of air pollution such as ozone or acid rain (indicated by Pb deposition) on the bog surface will result in a reduction in preservation state; (5) dessication of the bog surface during periods of dry summers (repre-