Vacuum freeze-drying of sediment cores: an optimised method for preserving archaeostratigraphic archives

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The authors introduce an ongoing project that explores a solution for the long-term preservation of proxies in archaeological and geological sediment cores to protect unique palaeoenvironmental data. To prevent alterations of organic properties and/or fungal growth, the sediment cores are vacuum freeze-dried, allowing long-term storage at 55 per cent relative humidity (RH).

Keywords: archaeostratigraphic archive, cost-efficient storage, sediment cores, palaeoenvironmental data

Introduction

Unearthed and undisturbed sediment sequences hold substantial potential as unique stratigraphic archives that contain vital information on archaeological, climatological and palaeoecological contexts. The stored sediments and soil samples from older excavations, however, are often at risk due to changes (e.g. micromorphological structural damage and collapsed pollen) that can occur during post-excavation storage (Blake *et al.* 2000). The archived organic resource as a valuable future research potential contradicts the reduction in financial investment in museum and archive repositories that is leading to dwindling resources, facilities and in-house skills (Ray *et al.* 2013). It is therefore crucial that these storage challenges are met by technical solutions—both to secure present sediment cores and to enable an increase in contextual environmental research. This project aims to develop a preservation strategy for the long-term storage of archaeostratigraphic sediment cores that accommodates future research and, additionally, reduces energy consumption.

Prevailing procedures

Archaeological excavations and palaeoclimate field studies are often costly, long-term and complex endeavours. One strategy is to extract sediment cores to accommodate the requirements of present and future in-depth analyses (Figure 1). This method, however, leaves

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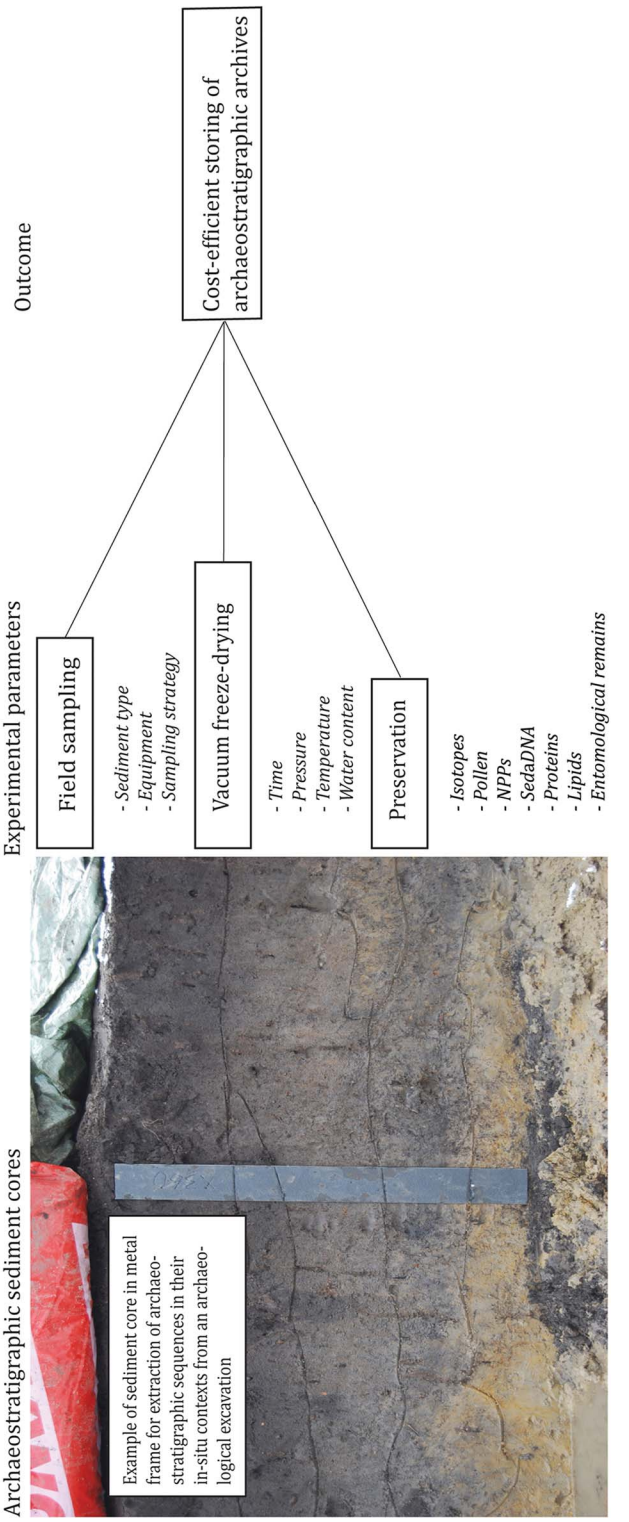

Figure 1. Overview of experimental parameters in the survey setup (photograph courtesy of Moesgaard Museum).

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excavation leaders, museums and universities with large quantities of sediment cores for storage (Harrison *et al.* 2016). As air-dried sediments will lose important physical properties, the prevailing procedure is to store sediment cores in cold stores. As an example, air-filled palynomorphs (microscopic plant and animal structures) tend to collapse under uncontrolled dehydration in ambient conditions (Fægri *et al.* 1989). Long-term storage in cold stores also results in the slow drying of the sediment and/or fungal growth on and inside the cores, as well as changes in biochemistry, bacteriology and bulk carbon properties (Clark & Hirsch 2008). The latter especially can bias radiocarbon dates, and NPP (non-pollen palynomorph) and sed*a*DNA (sedimentary ancient DNA) analysis. As a result, comparative studies have revealed that freezing is more suitable for long-term storage of environmental samples (Sun *et al.* 2015). Freezing is, however, not sufficient to preserve all organic properties, even with fast nitrogen-freezing (Thieme *et al.* 2016); when frozen uncontrolled drying will still occur. Therefore, new solutions are urgently needed.

Vacuum freeze-drying of sediment cores

Palynological laboratories often vacuum freeze-dry small sediment samples to preserve the morphology and structure of palynomorphs, such as pollen (Tirlea *et al.* 2015). In preliminary studies, we have compared pollen preservation in soil samples from a vacuum freeze-dried sediment core with pollen preservation in fresh samples from the same sediment core and found a convincing equivalence. We therefore propose to introduce vacuum freeze-drying, under controlled conditions, of smaller and larger sediment cores in order to preserve several proxies, such as palynomorph morphology, sed*a*DNA and NPPs for long-term storage (Figure 2). As a prerequisite, the treatment will prevent slow drying and cracking of the sediment surfaces, microbial alterations of organic properties and/or fungal growth on the core surfaces.

We will explore the possibilities of a controlled vacuum freeze-drying of sediment cores and conduct experiments using:

Figure 2. The large freeze-dryer at the Moesgaard Museum is ideal for the processing of sediment cores under controlled conditions such as time, pressure, water content and temperature, as well as energy consumption (photograph courtesy of the Moesgaard Museum).

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i) Highly flexible software, in terms of semi-automatic or fully manually controlled.
ii) Wireless temperature probes.
iii) Experimenting with a range of pressures, freezing temperatures and time intervals.
iiii) Different sediment types, such as gyttja, peat and sand.

Our analytical work will include a review of the North European storage facilities, long-term costs of energy consumption and the future need for archaeostratigraphical archives. The outcome of this project will facilitate future climate, palaeoecological and archaeological research, and will have the potential to be implemented on a worldwide scale. The preliminary studies are supported by Moesgaard Museum, and further funding will be applied for during the subsequent international collaboration.

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