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Impregnation method for detecting annual laminations in sediment cores: An overview

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Abstract

Annually laminated sediments can provide an absolute time scale (by varve counting) and a high-resolution palaeoclimate information (from varve thickness). Both types of information may be directly measured from sediment core surfaces. In this paper, we stress that varve counting and varve thickness measurements derived from fresh core surfaces could not systematically reveal the internal sedimentary structure, even if assisted by high resolution image analysis. We present an example of a homogeneous sediment core for which the varves were only observable after core impregnation and polishing steps. Because the impregnation methods are not yet standardized, the aim of this paper is to give an updated review of the methodology. In this review, we present the major critical points during impregnation steps. In particular, we focus on all of the post-treatment sediment disturbances that can alter the laminated micro-structure and, consequently, varve measurements. Finally, we propose a modified impregnation protocol, especially adapted for tracking varved intervals in long cores.

Keywords: Laminated sediments; Polymerization; Thin-section; Varve dating; Palaeoclimate analysis

1. Introduction

High resolution palaeoclimatological data reconstructed from annually banded archives (e.g., tree rings, speleothems, corals, ice cores, varves) constitutes the basis for inter-comparison of past climate variability (e.g., Holivar programs: Battarbee, 2003). Of these approaches, the marine and lacustrine varved cores sequences represent some of the highest-resolution materials useful for tracking short-term climate changes calibrated with absolute time scales (c.f., Kemp, 2003). Because such archives are wet and unconsolidated, counting the varves directly from the fresh core surface may underestimate the correct number of varve years (Lotter and Lemcke, 1999). One particularly attractive method consist of impregnating the sediment core with polymers in order to more easily prepare thin-sections (Kemp et al., 2001). This step is essential for being able to count each "varve year" (e.g., Lamoureux, 2001). Since the

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1960s, the evolution of impregnation methods has been strongly linked to the development of innovative technique (e.g., sampling devices, cryogenic and vacuum technologies, polymers, etc.). Originally, sediments were simply covered by resins, with impregnation assisted by gravity (Heezen and Johnson, 1962; West, 1966; Shannon and Lord, 1967; Moreland, 1968; Orlansky, 1968). Later, total impregnation techniques developed by pedologists for soil micromorphology (Altmuller, 1962) were adapted in order to emphasize the muddy material (Ashley, 1973). At the present there are still two embedding methods in existence, but they have not been standardized (Lotter and Lemcke, 1999). In this paper, we first review the available protocols for resin impregnation of varved sediments. We then propose a revised method that may be useful for tracking the internal sediment structure in long marine cores. The modified criteria are discussed in terms of efficiency for varve identification, especially in clayey material.

2. Review of the impregnation methods

Impregnation methods require three major steps, namely sampling, sediment dehydration, and polymerization. Descriptions of the protocols are presented in the accompanying literature review (Table 1). Note that this review does not include the sediment disturbances related to the different drilling systems (see Lamoureux, 2001).

Table 1
Review of published methods for sediment core impregnation

Impregnation step	Literature protocol	References
Core cutting	Electro-osmotic core cutting	Schimmelmann et al. (1990)
	Frozen core cutting	Lotter and Lemcke (1999)
	Sub-sampling boxes	Francus and Asikainen (2001)
Dehydration	Acetone in liquid phase	Conway (1982), Clark (1988)
	Acetone in vapor phase	Camuti and McGuire (1999)
	Freeze-drying	Pike and Kemp (1996)
Impregnation	Acetone–resin-exchange	Lamoureux (1994)
	Under vacuum	Lotter and Lemcke (1999)
Polymerization	Oven (20–40 °C)	Ashley (1973)

See text for explanations.

2.1. Core sampling

Core sampling is an important part of this procedure because the cohesion of the muddy material must be maintained. Conventional sampling methods (i.e., syringes, spatulas, plastic bags) cannot be used because they are destructive. Published methods to collect undisturbed samples from the cores used overlapping aluminium foil boxes pushed down the working sections. The boxes are designed to accommodate the dimensions of thin-sections, or longer (e.g., 180 mm long × 20 mm wide × 7 mm deep; Francus and Asikainen, 2001). The sub-sampling boxes are easily extruded from the cores without damage to the sediment material by using a monofilament, a square of sheet metal (Lamoureux, 1994), or by using an electro-osmotic core cutting device (Chelmik, 1967; Bouma, 1969; Sturm and Matter, 1972; Schimmelmann et al., 1990; Francus and Asikainen, 2001; Kemp et al., 2001).

2.2. Dehydration techniques

Core material composed of fine clays with unstable physical properties cannot be air-dried in the same way as can sandy sediments. Conventional drying procedures (e.g., oven-drying) are responsible for shrinkage and distortion of the clay matrices (e.g., Tanner and Leong, 1995). One solution for preserving the sediment microfabric during the drying phase is to decrease the water content with successive solvent baths, e.g., by water/acetone removal (e.g., Pusch, 1999). The acetone exchange method may be done in liquid-phase (Conway, 1982) or vapor-phase (Camuti and McGuire, 1999). In the use of liquid phase exchange, sediment is soaked in a container with acetone. One sample requires eight consecutive acetone baths over a period of one week, while measuring the baths specific gravity in comparison with pure acetone (Clark, 1988). In the case of vapor phase methodology, sediment is placed under acetone vapors in a dry chamber for three weeks (Camuti and McGuire, 1999).

The other solution to the shrinkage problem is the lyophilization (freeze-drying) technique that evacuates the interstitial water by sublimation (Bouma, 1969;