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NOTE

A simple and effective method for preserving the sediment–water interface of sediment cores during transport

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Abstract We describe a method for preserving the upper sediments of fragile sediment cores during transport from field sites and assess potential effects on subsequent laboratory analyses. This method addresses the need to minimize disturbance to the surfaces of unfrozen sediment cores used for paleoenvironmental or other high-resolution sedimentological analyses during transport. A polymer gel (sodium polyacrylate) applied above the sediment surface acts as a barrier to movement while also preserving surface undulations. The gel seal can preserve even exceptionally fine sedimentary structures (<0.2 mm) in the upper sediments of lacustrine and fiord sediment cores, but may react with organic material (e.g. algal mats) present on some sediment surfaces. This reaction creates an adhesive layer at the gel's base but it can be handled effectively during sampling. The gel seal minimizes surface deformation and preserves surficial sediments better than traditional seals made of water-absorbent floral foam, wax or paper towel. In addition to permitting detailed sedimentary and subfossil investigations of the sediment–water interface, this method shows no detectable effects on measurements of total organic carbon or total nitrogen values in the sediment. This method is inexpensive, non-hazardous and applicable to many coring systems and sediment types.

Keywords Sediment cores · Sediment–water interface · Sediment disturbance · Paleoclimate studies · Sedimentology

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Introduction

Collecting high-quality sediment cores is necessary for developing accurate and reliable data to be used for environmental reconstructions from lacustrine and marine environments. Recent environmental change is an important topic of research in paleolimnology, and the recovery of undisturbed surface sediment cores is especially important for analysing modern environmental changes. However, in most settings, the uppermost sediments have a relatively low bulk density and high water content that increase their susceptibility to even minor disturbance (Glew et al. 2001). As such, a major challenge associated with sampling soft lacustrine and marine sediments is retrieving sediment cores with intact and undisturbed sediment–water interfaces. If cores are not subsampled in situ, shipment to the laboratory without damage to the surface sediments can present significant challenges (Glew et al. 2001; Lamoureux 2001). While freezing may be one option to stabilize the sediments, many high-resolution physical and chemical analyses performed on sedimentary records require undisturbed and unfrozen sediments, and the freezing process may induce significant disturbance through ice crystal growth. Minimal surface sediment disturbance is especially important for geochronological analyses of radioisotopes (e.g. ^{210}Pb or ^{137}Cs) and for determining annual lamina (varve) chronologies (Lamoureux 2001), as these records are often the primary chronological bases for paleoenvironmental analysis.

Many researchers have developed and tested coring techniques for retrieving undisturbed surface sediments (e.g. Blomqvist 1985; Leonard 1990; Blomqvist 1991; Fisher et al. 1992), but techniques for preserving the core tops during transport have not frequently been reported. In most coring techniques that preserve the sediment–water interface, water is removed from the core tube above the sediment surface immediately after retrieval to prevent mixing at the sediment–water interface. Additionally, cores are often stored vertically in an above-freezing location, to further minimize the potential for disturbance. Cores can dewater during this time, which allows the upper sediments to consolidate more and become less susceptible to disturbance during subsequent transport. However, there is often insufficient time available in the field for dewatering and, therefore, other methods of preparing the sediment–water interface for transport are necessary. While water-absorbing floral foam has been used successfully to minimize disturbance, it can leave room for the sediment to move as the sediment continues to dewater and it does not aid in the preservation of surface undulations. This foam may also shift during transport and thereby disturb surface sediments. Similarly, paper towel or other solid, water-absorbent media placed between the sediment surface and the tube seal may absorb moisture but can also disturb the surface sediments and any void space can create the potential for sediment movement.

In this study, a technique using a gel seal above the sediment surface was evaluated as a way to minimize surface sediment disturbance during sediment core transport from field sites without compromising the structural and chemical integrity of the sedimentary record. This method was briefly mentioned by Glew et al. (2001) but its effectiveness has not been evaluated. This procedure is intended for intact preservation of the sediment surface when unfrozen sediment cores are required.

The gel seal method

We report here on the effectiveness of sodium polyacrylate, a non-toxic, gel-forming agent, for core surface preservation. It is generally available in various forms from medical suppliers as an absorbent of biomedical spills. In our study, we used Zorbitrol® Plus Superabsorbent Polymer (Ulster Scientific Incorporated, New Paltz, NY), which is a sodium polyacrylate powder that can absorb many times its weight in water (Lukens Medical Corporation 1996). In our laboratory test, 100 mg of this powder was sufficient to absorb up to 25 ml of distilled water while maintaining a thick consistency. The gel began to lose its structural integrity if more water was added.

To examine its effectiveness in preservation of the sediment–water interface, sodium polyacrylate was used on eleven lacustrine (Lake A, 83°00′ N, 75°30′ W) and five fiord sediment cores (Disraeli Fiord, 82°52′ N, 73°30′ W; Markham Fiord, 82°56′ N, 71°05′ W; and Ayles Fiord, 82°40′ N, 78°45′ W) collected along the northern coast of Ellesmere Island, Nunavut, Canada, during May and June of 2006 (site descriptions and maps are given in Van Hove et al. (2006) and Mueller et al. (2006)). These cores were returned to the field camp from sample locations via helicopter. The intact cores were then transported by air and land to laboratories over 4,000 km away at Queen's University (Kingston, ON) and Université Laval (Québec, QC) for fine-scale sampling (1 mm) and thin section preparation, among other analyses.

The sediment cores were collected using messenger-operated gravity and percussion coring systems (Aquatic Research Instruments, Hope, ID). The cores were taken from water depths of 11–82 m (Lake A), 48–140 m (Disraeli Fiord), 43–127 m (Markham Fiord) and 80 m (Ayles Fiord). After coring, the corer was carefully removed, the tube bottom was sealed and holes were made in the core tube above the sediment–water interface with an awl to release the overlying water slowly. At least 2–3 cm of water was retained in the core tube in order to prevent disturbance of the sediment–water interface. While holding the core vertical and still, a sufficient amount of sodium polyacrylate was added to the core tube to absorb the water and form a stiff gel that moulded to the surface contours of the sediment sample within 1–2 min. To determine the amount of sodium polyacrylate required to absorb the water, approximately 1 g of powder was initially added and observed as the gel formed. If the gel did not have sufficient viscosity after 1–2 min, additional sodium polyacrylate was added until a thick gel seal developed. After formation of the gel seal, a small amount of dry sodium polyacrylate was added on the top to absorb any water released during transport to the field camp, and the top of the core tube was capped and sealed with tape. This on-site addition of sodium polyacrylate allowed for the removal of excess water from the core tube without disturbing the uppermost sediments and preserved the form of the sediment–water interface.

The cores were stored vertically in the field camp and allowed to dewater for up to one week. During this time, more sodium polyacrylate was added, as necessary, by sprinkling powder on top of the gel seals to thicken them as dewatering occurred. Just prior to shipping, extra dry powder (approximately 500 mg) was sprinkled on top to absorb any water released during transport from the field camp to the laboratory. Loosely bunched paper towel filled any remaining space between the top of the gel and the core cap and the cap was taped securely to the tube. The additions of sodium polyacrylate in the field camp prior to shipping were for maintenance of thick gel seals and to reduce the risk of damage to the sediment–water interfaces due to water released from the cores during travel to the laboratory. Ten lacustrine sediment cores were transported vertically to Queen's University and one lacustrine and all fiord sediment cores were transported horizontally to Université Laval in protective cases.

Physical influences on the upper sediments

Thin sections (embedded sediment slabs) are sometimes used for detailed sedimentological studies, and particularly for varved sedimentary records (Lamoureux 2001). Undisturbed surface sediments are necessary for varved sediment studies not only to obtain good thin sections, but also to compare varve chronologies to dated instrumental or proxy climate records. Without the uppermost varves, the sediment chronology does not have an accurate starting year and cannot be easily compared to other records. In this study, thin sections were used to assess the effectiveness of sodium polyacrylate in preventing the disturbance of surficial sediment laminae during transport. Based on previous work at the study lake, our lacustrine sedimentary cores were known to have extremely thin varve structures (<0.2 mm). These fragile units were particularly useful for the purposes of this study.

In the laboratory, the sediment cores were split lengthwise and the gel seal was carefully removed from the sediment surface. The only problem in removing the gel arose in cores that had organic material at the sediment surface. The organic material appeared to react to the gel, creating a stiff, adhesive gel layer (2–3 mm thick) at the bottom of the gel seal. The overlying gel was removed easily but the adhesive gel layer had to be handled carefully during sampling. For thin section preparation, the adhesive gel layer was cut carefully such that a thin unit of the layer remained in the uppermost thin section of each affected core. Thin sections were made following the methods of Lamoureux (1994, 2001), which involved dehydrating the samples in acetone and embedding them in a single application of Spurr's low viscosity epoxy resin under low vacuum. The residual gel did not adversely affect polymerisation of the epoxy resin. When sampling for other analyses, sediment grains attached to the base of the adhesive gel layer were carefully scraped off and added to the uppermost sediment sample. As such, the adhesive gel layer could be handled appropriately for different analyses without compromising the sampling process. Cores that had clastic material at the sediment surface (i.e. minimal organic material, no algal mats) did not form an adhesive gel layer and had no discernable disturbance due to the gel seal.

No sediment–water interface can be preserved perfectly and, given the exceptionally fine structure of the lacustrine cores used in this study, all cores showed some disturbance at the surface induced by the coring process. However, only two of the nine lacustrine sediment cores that were subsampled for thin section preparation showed disturbance (mixed sediments to 7 and 20 mm, respectively) that hindered thin section analyses. The gel seal, however, did not appear to be the cause of the disturbances, as no gel was incorporated into the sediment. Thin section analyses suggested that the fine laminae in the lacustrine sedimentary record were likely disturbed by the coring process or by handling before the addition of sodium polyacrylate. The remaining cores had intact microlaminae (mean thickness <0.3 mm in the uppermost 2 cm) and could be cross-correlated at the surface, indicating minimal disturbance (Fig. 1). The slight disturbances evident in the surface sediments of these cores involved small areas of mixing or deformed laminae that did not inhibit thin section analyses. The gel seal also preserved uneven surfaces, although settling throughout the core permitted some flattening over time (Fig. 1). In some cores with irregular tops, void spaces extended down the side of the core tubes. Gel formed in these voids when sodium polyacrylate was added to the cores and, thus, preserved the spaces and prevented surface sediments from shifting into the voids during transport. Additionally, the fiord cores and single lacustrine core that were transported horizontally generally showed little to no surface disturbance, based on thin section (lacustrine core) and core face (fiord cores) analyses. Although slight deformation was apparent at the top of the lacustrine sediment core, it did not hamper thin section examination.

During core collection at the same lake in 2005 with the same coring equipment, we used water-absorbent floral foam to protect the sediment surface.

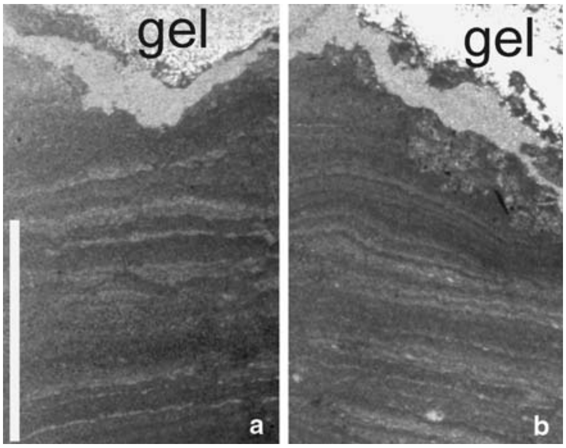

Fig. 1 Backlit thin section scans (2,400 dpi) from two cores from 2006 (scale bar = 5 mm). (**a**) Surface undulations were preserved and microstructures (<0.2 mm) were not substantially affected by the gel seal. (**b**) Both coarse and fine surface deposits were not notably disturbed

These cores were disturbed by subsequent transport substantially more than those capped with sodium polyacrylate, and five of the seven thin-sectioned cores showed notable disturbance (mixing and deformation) in the top 7–29 mm that hindered thin section analyses.

Chemical influences on the upper sediments

Carbon and nitrogen levels are often measured in the sedimentary profile to examine relative levels of aquatic and terrestrial productivity over time (Meyers and Teranes 2001). To determine if the addition of sodium polyacrylate had an effect on sediment carbon and nitrogen levels, total organic carbon (TOC) and total nitrogen (TN) measurements were conducted. A sediment sample ($\sim$4 g) was taken from 5 to 5.5 cm depth in one of the lacustrine sediment cores from 2006 and was mixed and halved. This sampling depth was chosen because it was considered to be too deep for influence by the gel seal and it would be representative of the laminated upper sedimentary record. Approximately 5 mg of sodium polyacrylate, mixed with 1.5 ml of distilled water, was added to one half of the sample and the other half remained untreated. Additionally, TOC and TN measurements were taken throughout two cores taken from the same area of the study lake in 2005 (floral foam seal) and 2006 (gel seal) to examine potential chemical influences of the gel seal on the upper sediments. All samples were pretreated with dilute hydrochloric acid (2 N) for 24 h to remove carbonates and thoroughly rinsed with distilled water before measurement in a Leco CNS-2000 analyser.

Table 1 Summary of TOC and TN analyses of the treated and control samples. The ranges of measurement error for TOC and TN are also shown. They are based on two standard deviations (2σ) from the mean TOC and TN values of standard blank (empty) samples (TOC, $n = 95$; TN, $n = 101$) (L. Cameron, pers. commun.)

Sample treatment	TOC (%)	TN (%)
Gel seal (treated sample)	2.07	0.13
No gel seal (control sample)	2.01	0.13
Analyser error range (2σ)	0.03–0.10	−0.04–0.05

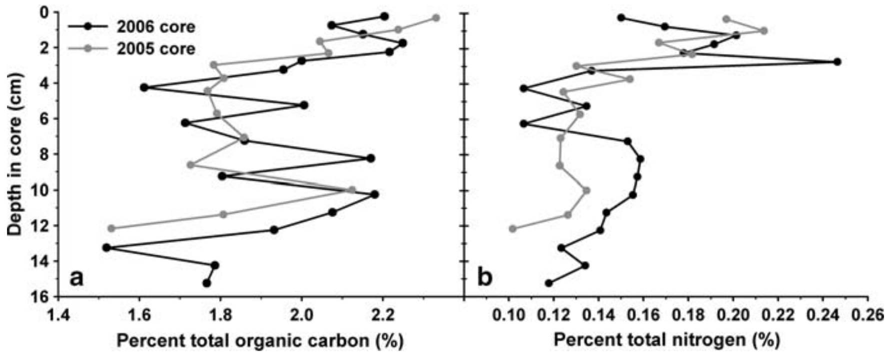

Fig. 2 (**a**) TOC and (**b**) TN profiles from the upper sediments of 2006 (black lines) and 2005 (grey lines) cores obtained from the same area of Lake A. The 2006 core had a gel seal and the 2005 core had water-absorbing floral foam as a core tube seal. The 2005 core's sampling depths were adjusted to corresponding depths in the 2006 core using marker beds

The control and treated samples from 5 to 5.5 cm depth showed no substantial difference in their TOC and TN levels (Table 1). The difference between each set of values was within the measurement error range and indicated negligible influence by the gel seal. The TOC and TN profiles revealed some differences between the 2005 and 2006 cores but no trends were evident to suggest substantial changes in these chemical constituents towards the top of the 2006 core, where the gel seal would have had the most influence (Fig. 2). The upper sediments of the 2006 core showed slightly lower levels of TOC and TN than the 2005 core, and, hence, the gel seal did not cause any organic enrichment. The deviations in the profiles may have been due to slight offsets in depths between the cores, surface sediment disturbance in the 2005 core or variations in organic sedimentation at each core location.

Although the gel seal did not appreciably alter the carbon and nitrogen components of the sedimentary record, replicate testing should be conducted to confirm these initial results. The influence of sodium polyacrylate on other common paleoenvironmental analyses remains yet to be verified. This preservation technique is particularly useful for field work in remote locations where transport may be lengthy, but it is applicable to many situations where sediment surface preservation is important for modern environmental change analyses.

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