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A sledge microtome for high resolution subsampling of freeze cores

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Abstract We describe a sledge microtome designed for the high-resolution subsampling of freeze cores. This inexpensive freeze-core microtome is capable of producing precise subsamples at mm to sub-mm resolution without sediment loss and cross-contamination. Such a subsampling resolution permits recognition of sub-decadal to annual events even in systems with low sedimentation rates. The freeze-core microtome is particularly useful for obtaining high-resolution subsamples at the environmentally important sediment-water interface due to freeze corers being capable of capturing this boundary with minimal disturbance as compared to other coring methods.

Keywords Microtome · Freeze core · Water–sediment interface

Introduction

High-resolution temporal records are invaluable to paleoenvironmental reconstructions in the fields of paleolimnology and paleoceanography (Kulbe and Niederreiter 2003; Blass et al. 2007). Climate cycles and oscillations (El Nino/Southern Oscillation, Pacific Decadal Oscillation, various solar cycles) archived within lake sediments, require a sub-decadal sampling resolution in order to be recognized (Renberg 1990; Patterson et al. 2004; Chang and Patterson 2005; Patterson et al. 2007; McKay et al. 2008). High-resolution studies of anthropogenic impact are also necessary to establish the degree of environmental alteration and monitor restoration efforts (Smol 1995). Unfortunately, most suitable lacustrine (Gasiorowski 2008) and marine (Reading 1996) systems are characterized by low sedimentation rates, where the standard core subsampling resolution of 0.5–10 cm is typically insufficient to detect many important paleoclimate and paleoenvironmental signals (Patterson 1993).

In this paper we describe the construction and application of a custom-designed sledge freeze core microtome intended for precise and accurate millimeter to submillimeter-scale core sampling of freeze cores. The impetus for the development of this device was the mm-scale subsampling strategy required to examine sediment cores at decadal to sub-decadal resolution. Our device is specifically designed to subsample freeze cores, which are ideally suited for the recovery of high-quality sedimentary sequences (Lotter et al. 1997; Kulbe and Niederreiter 2003; Blass et al. 2007). This sampling capability extends to the generally highly unconsolidated and water saturated sediment near the water interface, which is

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difficult to recover undisturbed using most other corers (Lotter et al. 1997; Glew et al. 2001; Kulbe and Niederreiter 2003; Blass et al. 2007).

The use of cryo-chambered sledge microtomes in various biomedical disciplines has been long established and these commercially available instruments can produce serial sections down to only a few microns thick. However, even the largest of these devices are only satisfactory for sectioning objects in the mouse-size range, and they are very expensive. More applicable to sedimentological applications, Cocquyt and Israël (2004) developed a custom microtome for high-precision subsampling of certain soft sediment cores, at mm resolution. That instrument is unfortunately not suitable for slicing freeze cores, and is incapable of subsampling the soupy sediments that characterize the sediment–water interface and upper portions of many lacustrine cores without application of a dewatering procedure (Cocquyt and Israël 2004).

Description

The sledge freeze core microtome (Figs. 1, 2, 3) is constructed of aluminum and composed of two main parts, a table assembly (a) and a sediment cutter assembly (e–m). The table assembly has two parts; a metal ramp (a), and a polyethylene plastic cutting board (b) which snaps onto the metal ramp (d). Spaced at regular intervals along the cutting board are height-adjustable brass spikes (c) that help fix the core to the cutting board. The bottom of the cutting board is also equipped with clips (d) that facilitate the quick exchange of boards, so one can slice another section of the core while a previous section is frozen again.

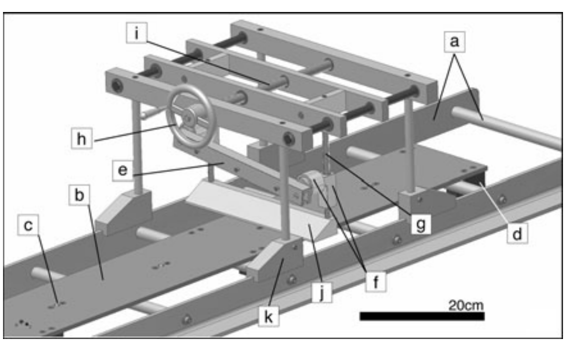

Fig. 1 CAD image of cutter assembly attached to table assembly of the freeze core sledge microtome. Parts of the microtome: metal ramp (**a**), plastic cutting board (**b**), brass spike (**c**), plastic clip (**d**), knife holder (**e**), pivot (**f**), rod (**g**), crank wheel (**h**), bolt (**i**), metal foot (**j**), sediment cutter foot (**k**)

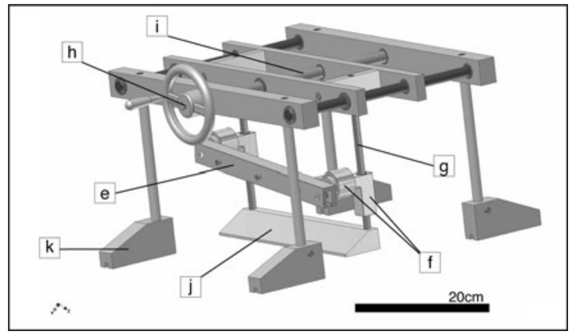

Fig. 2 CAD image of cutter assembly. Parts of the microtome: knife holder (**e**), pivot (**f**), rod (**g**), crank wheel (**h**), bolt (**i**), metal foot (**j**), sediment cutter foot (**k**)

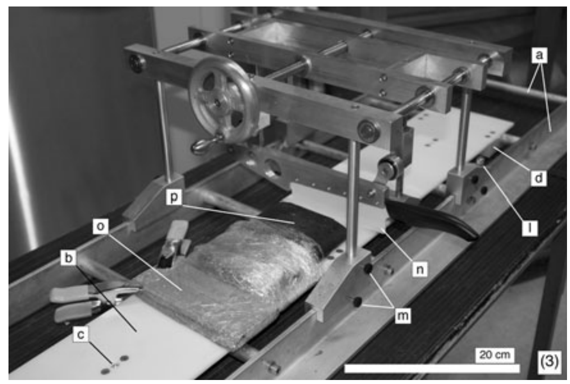

Fig. 3 Photograph of freeze core sledge microtome with sediment core section attached. Parts of the microtome: metal ramp (**a**), plastic cutting board (**b**), brass spike (**c**), plastic clip (**d**), adjustable pin (**l**), vice screws (**m**), blade (**n**), block (**o**) and sediment core section (**p**)

The sediment cutter assembly is composed of the knife holder (e), the knife holder pivot system (f), two rods for vertical movement (g) and the crank system (h–i) used to move the knife horizontally. A ceramic blade (n) is used since it is the sharpest available and also avoids any potential contamination issues associated with using a metal blade. The blade is secured by several nylon screws, permitting the easy removal of the blade for cleaning or storage. The knife holder is attached to two round pivots (f). Each pivot is attached to a rod (g), thus the pivots can be moved vertically simultaneously to raise the knife, or one at a time to raise or lower either end of the knife. The pivots also allow the knife to be moved in a pendulum motion perpendicular to the cutting board. This swinging ability extends the blade's cutting range and allows the researcher to rock the knife while slicing, greatly facilitating the process. The knife holder, the pivots and the rods are all suspended from the crank system (h–i). The crank system uses a bolt (i) with a pitch of 2 mm per revolution of the crank wheel (h). Notches around the circumference of the crank wheel (h) are calibrated to 0.2-mm movements of the knife along the cutting board. This allows the researcher to choose the desired slice thickness greater than or equal to 0.2 mm. A metal foot (j) that spans the base of the two pivot rods considerably reduces play within the pivot and rod system. Some play is present at the base of the blade (< 0.5 mm), but with practice and careful use precise and accurate cuts can be consistently achieved.

The feet (k) of the sediment cutter assembly fit onto the top of the metal ramp (a) (Figs. 1, 3). Small holes drilled along one side of the metal ramp allow for a pin (l) in one of the legs of the sediment cutter assembly to fit inside, adding stability while cutting. Small vice screws (m) in each foot of the sediment cutter assembly are then tightened to secure them to the metal ramp.

Operation of the microtome

As the name suggests, the sledge freeze core microtome is primarily designed to be used with freeze cores, although the instrument could be used for cutting any stiff sediment. Limits imposed on the size of the core are due to the height of the blade and the area that the blade can be rocked widthwise to cover. It is assumed that the freeze core sections will have a flat face (the face that was directly touching the freeze corer). The flat face is resting on the cutting board surface. The microtome can accommodate cores that are a maximum of 3.5 cm in height off the cutting board surface and a maximum of 19.5 cm in width. All cores that we deal with within our laboratory are massive in structure. The great benefit of this apparatus is the quickness with which a freeze core can be subsampled at millimeter intervals. With laminated sediment where the laminae are tilted width wise, it is possible to detach the cutting board from the ramp and rotate it to the desired orientation. This will add time to the procedure though.

As cores to be cut will be subsampled at high resolution it is extremely important that the core is not moved during processing. For best results the core is fastened to the cutting board using plastic wrap and tape and further stabilized using the adjustable brass spikes (c). A block (o) is also placed against the end of the core segment (p) furthest from the blade and clamped down to further immobilize the core during cutting.

It is very important that cores be at the right temperature before subsampling to ensure best results. To use a familiar analogy, freeze cores are similar to ice cream in consistency. When ice cream is frozen solid it is very difficult to obtain scoops and when it is too soft the results are similarly unsatisfactory. Accurately subsampling a completely frozen freeze core just removed from our −10°C cold room is not easily accomplished as it is difficult for even a ceramic knife to penetrate the sediment. Freeze cores must therefore be warmed slightly prior to cutting. In our facility a core to be cut is moved from the cold room to a 4°C cool room for 30 min. A core can be subsampled in this environment for ~90 min before it must be returned to the cold room. Each sediment slice is collected using a small spatula, which is used to push the slice into a vial held beside the cutting board. As long as the core has not been allowed to thaw too much, no sediment is lost on the knife blade or the cutting board surface. Two sets of measurements are taken periodically to ensure slicing precision and accuracy. A piece of tape runs the length of the core, and a straight line is drawn down its length allowing for the precise placement of the ruler during every measure. An absolute measure of the entire core length is taken, as well as a relative measure (the length from the edge of the cut face to a mark along the length of the tape).

A practical concern with this instrument is the stabilization of very short cores (less than 1 cm in length) as these cores are too small to be stabilized with plastic wrap and tape. When such a core is cut the furthest end from the knife tends to lift or may fracture into many pieces widthwise. This problem was solved by permitting the core to come up to a higher than normal cutting temperature so that there is less resistance against the knife. Cleaning the instrument between samples becomes very important when dealing with these very small segments. The help of an assistant is also beneficial when dealing with short core segments as the assistant can manually hold the core in place with metal spatulas. The use of fingers or hands to hold short cores in place is strongly discouraged as ceramic knives are capable of producing nasty cuts.

Presently many concurrent studies are employing the device in our lab and have no difficulty consistently slicing freeze cores at 1-mm resolution, noting no sediment loss or loss of precision due to cutting inaccuracy.

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