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A rod-less piston corer for lake sediments: an improved, rope-operated percussion corer

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Abstract

A lightweight, percussion corer, suitable for use in remote lakes of moderate depth, is described. The operation of the corer and suggestions for securing and transporting long sediment cores are presented. In particular, the design and use of a recovery pot, which allows the retrieval of undisturbed cores from sediments of unknown depth, is detailed.

Introduction

Taking cores of Holocene sediments from remote lakes can be problematic where heavy coring equipment is required. The transport of a suitable piston corer, and for those lakes with unreliable ice-cover, a raft may be prohibitive unless a number of people, or motorised transport, is available.

In accessible, shallow (less than about 30 m water depth at the site of coring) lakes, piston corers of the Livingstone-type, operated from a raft by wire or rope and rods have proved to be excellent (Wright, 1991). However, the coring rods and casing are unwieldy to carry to remote sites, and to use where water depths exceed about 20 m. As a result, the retrieval of sediment cores from remote lakes often involves motor, or air-transport, or many people, rather than being exploratory expeditions using lightweight equipment. Fieldwork is therefore relatively expensive and may cause significant disturbance in and around sensitive sites.

For previous Holocene palaeolimnological work, carried out in the Cairngorm and Lochnagar mountain areas of North East Scotland, the Mackereth minicorer (Mackereth, 1969) and Livingstone corers (Wright, 1967) have been used. This has necessitated helicopter transport to the mountain corries (Jones et al., 1990; Battarbee et al., 1999). Arctic and alpine palaeolimnological projects elsewhere in Europe (Cameron et al., in press), Asia (Flower et al., 1997) and Australia (Cameron et al., 1993), which are concerned primarily with post-17th century sediments, have required short gravity cores only. However, the weight and dimensions of piston coring equipment has prohibited the opportunistic retrieval of longer cores whilst visiting these inaccessible sites.

Our aim, therefore, was to modify an existing piston-corer design so that, working from open-water, it was possible to retrieve undisturbed Holocene sediment sequences. The device was also required to collect enough material for fine-resolution analyses of a number of physical parameters and biological groups, whilst maintaining the portability of gravity coring equipment. This paper describes a corer designed for the CHILL-10000 project (Korhola et al., 1999), where collection of sediments for the entire Holocene period was required. The mode of operation and significant modifications to earlier percussion corer designs are given below.

Components and operation of the percussion corer

A number of types of percussion corer, which can be operated in moderately deep water because they do not require metal rods, use a moveable weight to drive the core tube past a fixed piston into soft sediments (Huttenen & Meriläinen, 1975; Digerfeldt, 1978; Gilbert & Glew, 1985; Nesje, 1992; Reasoner, 1993; Miskimmin et al., 1996). The simple principle of these corers, and their potential lightweight, were thought to be ideal for our purpose. However, some features of their respective designs were found to be inappropriate. Some supplementary information to that presented in the published literature was also required in order to build the corer.
The design of our percussion corer is based largely on Digerfeldt's 'Mark 2' corer (Digerfeldt, 1978). The components of the modified corer and other relevant details are shown in Figure 1. The coring sequence is illustrated in Figure 2 and is outlined below.

A raft was formed from 2 lightweight (1 or 2 person) 'Neptune' inflatable boats strapped together and separated by 2 buoys to form a central well for the operation of the corer. In suitable water and weather conditions the corer might also be operated from a single, larger (3 person) inflatable boat. The coring platform can be secured in position by roping across small lakes or by using small anchors on the lake bed.

To assemble the corer, the piston rope is threaded downwards through the steel head tube and aluminium alloy head of the core tube holder, through the unattached core tube and tied off on the head of the piston. The piston, held by friction, is then put into place at the base of the core tube, and the core tube is held almost horizontal to fill with lakewater. To avoid loss of the corer the free end of the piston rope should be secured to the boat when it is not required for threading on components. The head of the core tube is then attached to the core tube holder.

Having accurately measured the water depth at the point of coring, the corer and core tube are suspended by the piston rope alone and lowered to a position so that the base of the piston lies about 20–30 cm above the surface of the sediment. At this stage any twist in the rope should be allowed to unwind. The piston rope is temporarily untied, keeping the corer in the same vertical position, whilst the weight stage, loaded with a suitable number of weights, is threaded on to the piston rope. The piston rope is re-secured and using a second rope the hammer is lowered on to the top of the corer. The starting position is marked on the hammer rope along with the potential fully extended length of the core tube. The hammering should be carried out particularly carefully for approximately the first 50 cm, indeed during this part of the coring a tapping or hammering action may not be required as the weight of the hammer alone may be enough to drive the core tube into the sediment. If care is taken over the initial drive of the core tube into the surface sediment, the sediment water interface of the core should be intact. A gravity corer is not therefore required in addition to sample the surface sediment.

Hammering is continued until the tube is fully extended or impenetrable sediment or rock is encountered. The use of temporary marks (duct-tape, gaffer tape) on the hammer rope acts as a guide. If necessary the hammer can be brought to the surface and additional weights added. The vibration felt through the ropes and sound of hammering can also be helpful in determining the progress of the core tube through the sediment.

When the drive is completed the hammer is brought to the surface and the piston rope temporarily untied to unthread the weight stage. The weight stage is replaced on the hammer rope by the recovery pot (Figure 3) . This is then threaded onto the piston rope and the piston rope is re-secured. The pot is lowered and allowed to engage the steel head tube of the corer. The corer and sediment core can then be hauled up, taking the load on the lifting pot rope to avoid sediment disturbance whilst keeping the piston rope taut so as to avoid sediment loss. Without the use of a recovery pot, if the corer did not penetrate fully (so that the piston did not reach the head of the core tube) significant disturbance to the sediment would occur when the corer was pulled up by the piston rope or wire. This is because tension on the piston rope would force the piston to the top of the corer resulting in movement of the water and sediment in the tube below.

In practice, using the recovery pot, the effort to recover a sediment core from 20 m water depth with 2 m to 3m of sediment was not excessive. To assist with the initial pull, an oar shaft can be used as a yoke so that two people can pull on the lifting pot rope. A clove hitch can be made to the yoke, by making two loops in the rope, without the need for a free rope end.

When the sediment corer and core reach the surface, the corer head and/or head tube may be detached from the core tube, taking care to keep the piston rope taut. The base of the core should be secured quickly with a bung or piston. In a lake with a slow sediment

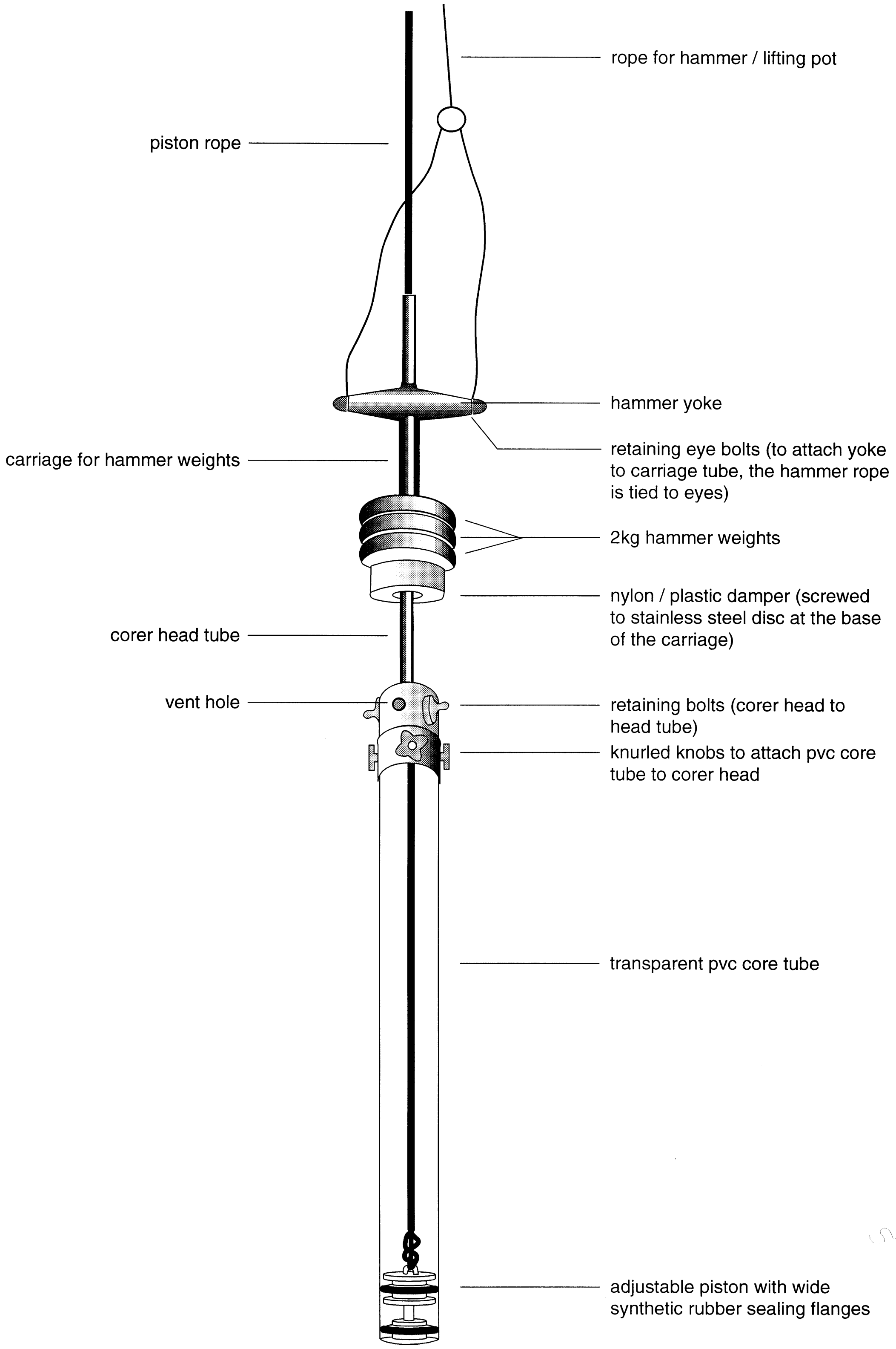

Figure 1. Components and outline details of the rope-operated piston corer.

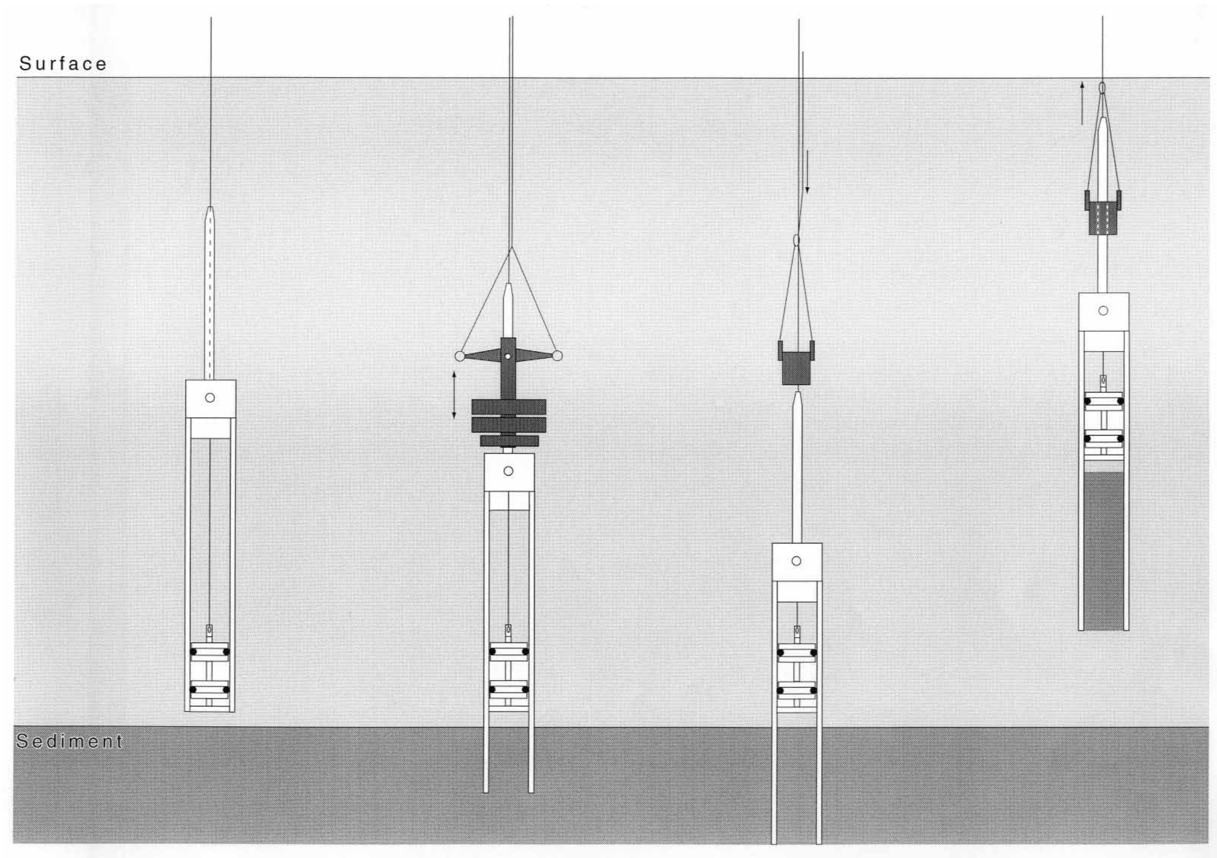

Figure 2. The sediment coring sequence, showing the: positioning of the corer; hammering and driving of the core tube into the sediment; retrieval of the corer and core sample.

accumulation rate it is possible to take a full Holocene sequence with an intact sediment water interface in a single drive. In many small, oligotrophic lakes in Europe, for example, the maximum Holocene sediment depth is often no more than 2.0–2.5 m.

Notes on the corer design

A number of new or redesigned features of this percussion corer are relevant to the construction of similar devices. These are outlined below. Published hammer weights were typically rather heavy for our purposes: Huttenen & Meriläinen (1975), 70 kg; Digerfeldt (1978), 15 kg; Nesje (1992) 10–20 kg although weights at the lower end of this range may prove to be necessary for longer cores. Bearing in mind the use planned for the corer, from an inflatable boat on open water, the ideal weight and fall of the hammer were arrived at by practical considerations rather than by calculation. The height of fall, without the stable platform and gantry provided by ice or by a raft, is limited by the comfortable range of movement of the arms or knees and should take into account the repetitious nature of the operation.

In order to reduce the weight carried to a lake, for the hammer, it is possible to use a container loaded with stones or sediment collected on site (Reasoner, 1993). However, here 2 kg bar-bell weights (12.7 cm in diameter) have been utilised and, based on the published literature, the designed height of our hammer allowed a maximum of 16 kg to be loaded. In practice we found that a total of 6 kg was adequate to penetrate 2.9 m of organic sediment. The individual weights have the advantage of being compact, commonly available, low in cost, easy to attach and remove.

A difficulty that has been reported with this type of percussion corer is the tangling of the fixed piston rope and the hammer or retrieval rope, particularly in increasing water depths. Therefore various arrangements

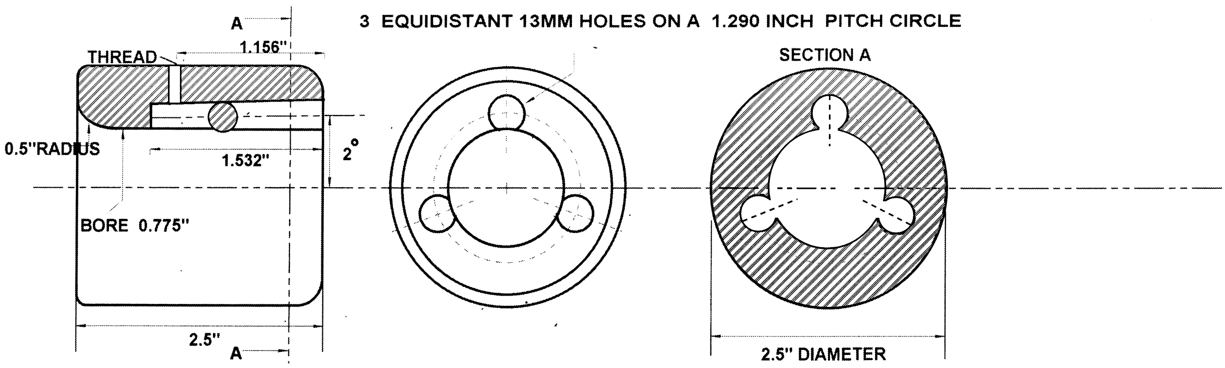

Figure 3. Details of the lifting device (recovery pot).

to separate the two ropes were considered. However, in testing and field use we have had no tangling of the two operating ropes. Digerfeldt's (1978) idea of a non-captive weight is possibly important here; the corer can be lowered into position above the sediment and twist allowed to come out of the rope before lowering the hammer into position. The use of a high quality rope for the piston may also be significant. Rope of the yacht racing type such as 'Spectra' or 'Kevlar' is ideal but the use of any good quality braided rope, as opposed to laid rope, is also important in avoiding excessive twist, kinks or tangling of the ropes. These types of rope also have the advantage of low elasticity and therefore it is not necessary to use a wire 'rope' for the piston. To allow for the internal diameter of the corer head tube and for ease of handling, a 6 mm or 8 mm diameter piston rope was used.

For the core tube we used cheap, flexible transparent PVC tubing. Tubing made from perspex (Plexiglas) or polycarbonate (Lexan) is often engineered to higher tolerances, but in the former case may shatter and the latter is expensive. However, the use of a large flanged piston with seals moulded from synthetic rubber compensates for the variable bore of the PVC tube and was found to maintain the seal without sediment loss. PVC core tube can also be cut with ease (see below).

The core recovery pot or lifting device outlined by Digerfeldt (1978) has the advantage of allowing the corer to be used at sites where the maximum sediment depth is unknown. A suitable angle and arrangement of steel ball bearings, which allows the pot to slide without jamming, and to pull up heavy loads without slipping, was determined from the trial of a number of models (see Figure 3). The act of lowering the pot onto the corer head tube pushes the ball bearings upwards in their races, making them a loose fit. The ball bearings move outwards because of the tapered bores. The vertical position of the recovery pot, on the corer head tube, does not appear to be critical in allowing efficient recovery of the corer, core tube and sediment core. However, we have usually lowered the recovery pot right to the base of the corer head tube, to rest on the head of the corer, before transferring the load to the recovery pot. Upon pulling upwards on the corer recovery rope, the ball bearings return to the base of their races and grip the corer head tube firmly.

Few tools are required to assemble the corer, and where possible parts of the corer have been designed to be assembled by hand. A portable tool to square and chamfer the PVC core tubes and to act as a template to drill core tube to core head connecting holes enables cutting and repair of core tubes to be carried out rapidly in the field.

We have found few problems with the operation of the corer. Although it proved to be possible to carry long cores upright, they are unwieldy to carry whilst trying to preserve an undisturbed mud surface. Subsequently, we have made safe the sediment water interface by trimming off any excess core tube (the part containing water) at the top. The remainder of the water (c. 5–6 cm) above the core top is then absorbed by plugging with porous 'Oasis' (This material is used by florists as a base in which to arrange cut flowers and is sold in the UK in bricks and cylinders. The latter, available with a diameter of approximately 75 mm, are ideal for plugging our core tube which has an external diameter of 75 mm and nominal wall thickness of 1.8 mm). A block of 'Oasis', of wider diameter than the internal diameter of the core tube, is simply pushed into the tube, the excess material is cut away by pressure against the edge of the core tube. This plug keeps the surface sediment intact in the tube. A sediment core, which is either too long or too heavy to carry easily, can be cut into manageable sections. All cutting of the PVC core tube was made using a wide diameter, plumber's pipe cutter (a tool resembling a G-clamp, with adjustable guide rollers at one side, and a cutting roller on the other side, of the jaw. Our device will cope with plastic tube of up to 81 mm in diameter). The pipe cutter has the advantage, over cutting with a hacksaw, of making clean, square cuts in the PVC tube, with no disturbance to the sediment and no particles of plastic arising from the cut. A thin steel or plastic slicing blade can then be introduced into the horizontal cut, the two sections of core separated, and the sediment at the cut ends capped. Since there is no sediment loss at the join, overlapping cores are not required.

The threading and unthreading of the weight stage and lifting pot from the free end of the piston rope requires tidy stowage of any excess rope. However, a weight stage or lifting pot constructed to clip on to the piston rope would complicate the simplicity of the present design. We hope that this device promotes the investigation of lakes in remote areas where palaeolimnology is under-developed.

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