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Equipment and procedure improvements for a lightweight, inexpensive, percussion core sampling system

Mel A. Reasoner
Department of Geology, University of Alberta, Edmonton, Alberta, T6G 2E3, Canada

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Abstract

This paper describes improvements for an inexpensive, lightweight percussion core sampling system and presents examples of recovered core. The system has proven most effective in remote settings where the weight of a coring system may be a constraint. Cores of up to 5.5 m in length have been recovered and the system has functioned successfully in water depths to 200 m. The system weighs approximately 25 kg and costs less than $450.00 (US).

The percussion corer is designed for operation from a stable ice-pack surface. The core barrel assembly is lowered through the water column and driven into sediment with a weighted driver. A secondary line is used to raise and drop the driver. The driver is guided to the core barrel assembly by the main line. Cores are retrieved by a simple pulley system anchored to the ice pack.

Introduction

In general, percussion coring systems rely on a weighted driver that can be raised and dropped on the top of a core barrel in order to force the barrel into sediments. Recent advances in percussion coring technology have resulted in the development of several closely related coring systems used in both marine and lacustrine coring situations (Gilbert & Glew, 1985; Reasoner, 1986; Nesje *et al.*, 1987; Nesje, 1992). The general trend of development has been toward systems that are unrestricted by water depth, lightweight and simple to operate, and more effective than gravity coring systems in terms of penetration and recovery.

Since the initial testing of the prototype corer in 1985 (Reasoner, 1986), at least 97 sediment core samples have been recovered using the original coring system and its modified versions described in this paper. In the process of recovering these cores, a number of refinements have been made to simplify the procedure and facilitate core recovery. Further, several structural modifications have been made to reduce weight and enhance the system's capabilities. The primary purpose of this report is to document these improvements and to point out some potential difficulties that may be encountered during operation. In addition, costs of materials and core splitting methods are discussed. Finally, several examples of recovered core are presented.

The system is ideal for operation in remote field settings because of its light weight and simplicity. It has been used successfully in the American and Canadian Cordillera, on Baffin and Ellesmere Islands in the Canadian Arctic, and at a number of locations throughout the Alberta Plains and Foothills. The system is designed for use on a stable ice pack surface although an anchored platform should be equally effective. The total weight of the system, equipped with lines for water depths of 50 m or less, has been reduced to approximately 25 kg. If all new materials and equipment are purchased, the cost of the system is about $450.00 US, excluding optional items (Table 1). The system is theoretically unrestricted by water depth and has been effective in shallow lakes and in fjords with water depths to 200 m (Lemmen, 1990). The longest core recovered to date measures 5.5 m in length and is thought to represent a continuous 24000 year record (M. Hickman, pers. commun. 1992). Finally, the corer has supported studies that require multiple cores from one basin (Beaudoin & Reasoner, 1992).

Table 1. Component costs.

Materials	
Core head	$20.00
Driver	$20.00
Core barrel (cost/barrel)	$10.00
Duct tape	$10.00
One-way valve*	$9.00
Reusable core catcher*	$200.00
Equipment	
50 m climbing ropes	$250.00
Ice screw	$30.00
Carabiners and slings	$25.00
Ascending device	$36.00
Pulleys (to fit carabiners)	$36.00
Pop riveter & rivets	$45.00
Vice grip pliers	$12.00
Screw driver set	$12.00
Ice auger	$80.00
Tin snips	$8.00
Battery drill*	$40.00
Total (CDN)	$595.00
(U.S.)	$450.00
With optional items (CDN)	$845.00
(U.S.)	$635.00

* Optional items

Equipment and assembly

The coring system is generally very similar to the original prototype (Reasoner, 1986) and consists of three major components; a core barrel, core head, and driver (Fig. 1). Lengths of 3 m PVC pipe (7.6 cm inside diameter, 0.32 cm wall thickness) are used as core barrels and are fitted with simple basket-type core catchers. The core catchers consist of 5 to 10 cm long fingers cut from galvanized sheet metal (Fig. 2) and are held in place by pop rivets. The rivits are flattened with pliers to reduce drag on the core. The bottom of the core catcher is cut into segments and folded over the outside of the core barrel and covered with duct tape.

The core head is a 1 m length of PVC pipe (7.6 cm inside diameter, 0.64 cm wall thickness) modified to fit on the core barrel. The driver is a 0.7 m to 1 m length of PVC pipe (10.16 cm inside diameter, 0.64 cm wall thickness) with end caps and a 2.54 cm internal guide pipe attached through the centre. Climbing ropes (11 mm and 5 mm) are used for the main line and the driver line, respectively. Cores are retrieved by setting up a pulley system on the ice surface that is anchored with ice screws (Fig. 3) or snow anchors.

Modifications

Improvements to the core barrel include addition of a reusable one-way valve, a reusable basket core-catcher/cutting-edge assembly, and a support hole for core removal. The one-way 7.6 cm valve, fitted in the top of the core barrel (Fig. 1), reduces suction on the core during retreival from the sediments. The valve is held in place by a rubber ring that is compressed against the walls of the core barrel. The only alteration to the valve involved the reversal of the compression screws so it could be easily fitted and removed through the top of the core barrel. The reusable core-catcher/cutting-edge assembly is shown in Fig. 4. The cutting edge is machined from stainless steel and provides a 2 mm choke to reduce friction as sediment enters the core barrel. Spring steel is

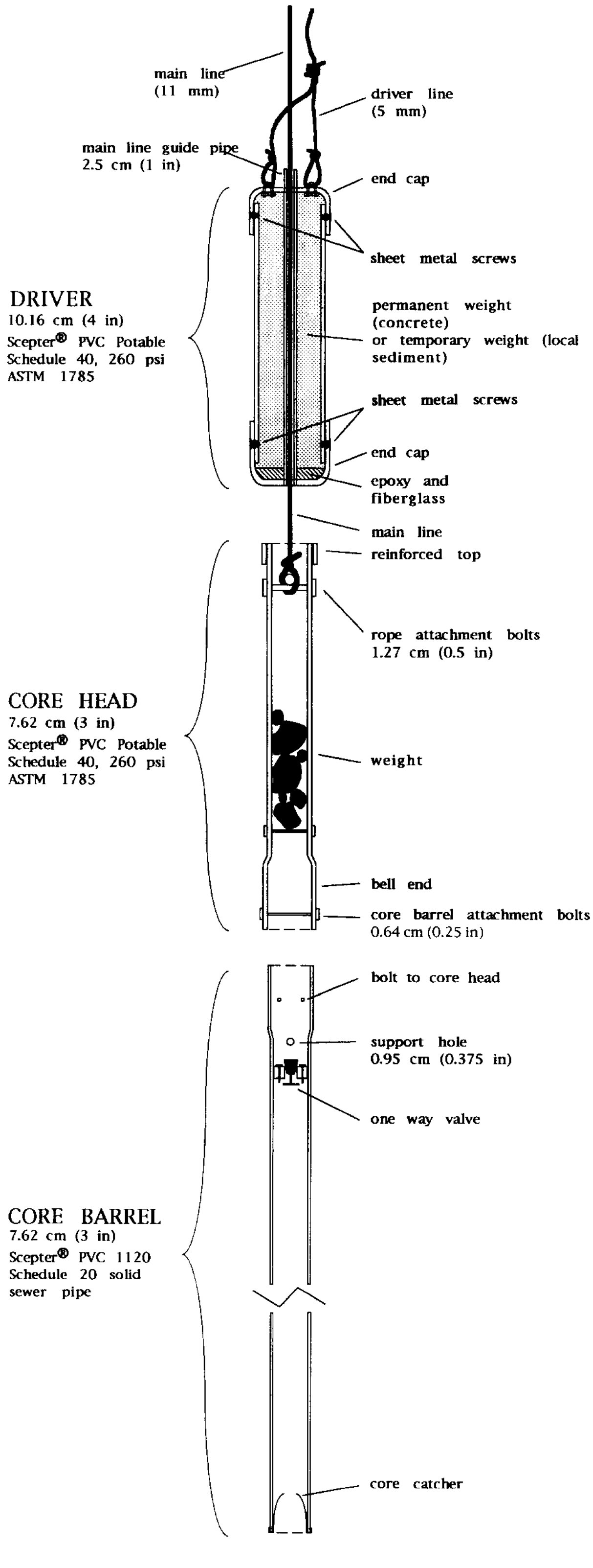

Fig. 1. Diagram of the coring system. The driver is raised and dropped approximately 2 m to drive the core barrel. The driver is guided to the core head-core barrel assembly by the main line. Imperial units are included because in North America these materials are sold only in Imperial sizes.

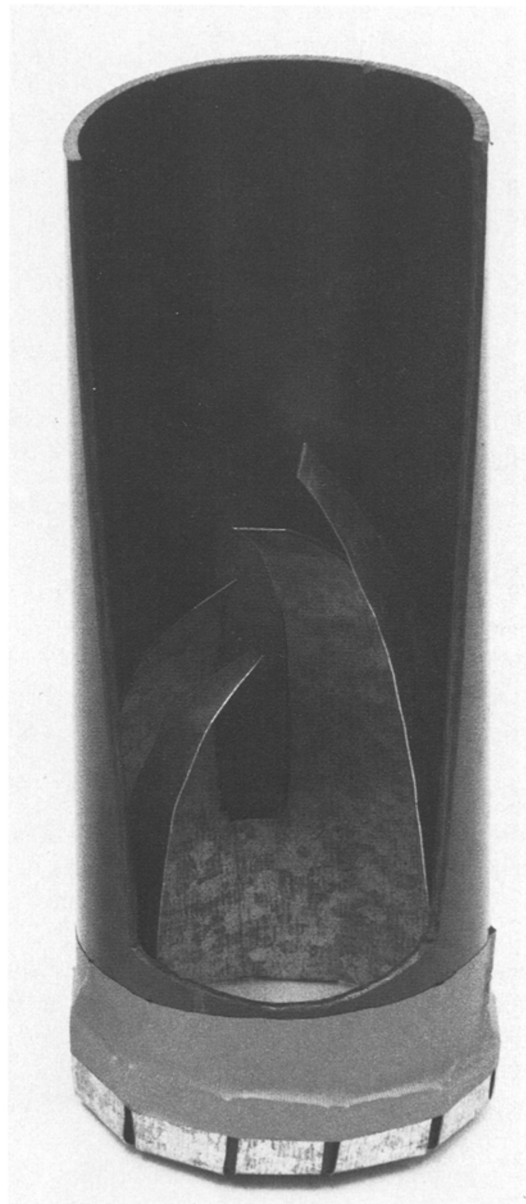

Fig. 2. Simple galvanized steel core catcher. Core barrel is 7.6 cm inside diameter.

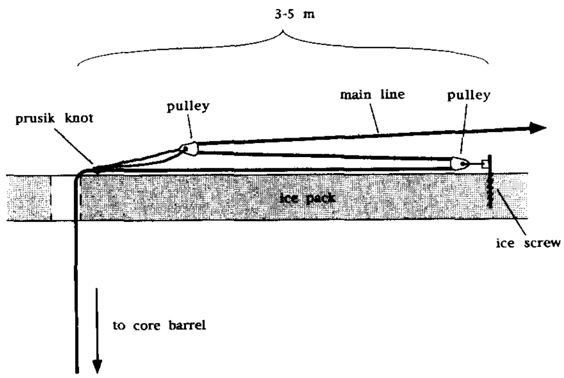

Fig. 3. Diagram of the core retrieval system. The mechanical advantage required for core removal is achieved using a simple pulley system anchored by an ice screw or snow anchor. The mechanical advantage can be increased by adding pulleys to the system.

used for the core catcher fingers to prevent the fingers from folding outward during core retreival. Finally, a 0.95 cm hole is drilled 15 cm below the top of each core barrel (Fig. 1) for insertion of a support rod during core retreival (described below).

The addition of a piston has been successfully employed (P. T. Davis, pers. commun. 1992) and is a possible alternative to the one-way valve. This configuration resembles a similar corer developed by Nesje (*et al.* 1987, 1992). The use of a piston, however, requires a third line, which increases the complexity and weight of the system. Most piston corers use a steel cable for the piston line. Further, the addition of a third line increases the potential for tangled lines, particularly in deep-water situations.

A simple modification to the driver allows it to be filled with local sediment or soil on site instead of a permanent filling of concrete (Fig. 1), which significantly reduces the system's total weight. In this case, both end caps are attached with eight sheet metal screws. This allows the driver to be dismantled in the field to facilitate loading and removal of local materials. The internal guide pipe is attached to the base end cap with PVC glue and reinforced with several layers of epoxy and fiberglass (Fig. 1). The guide pipe is not fixed to the upper end cap, but simply extends about 1 cm through the hole in the cap.

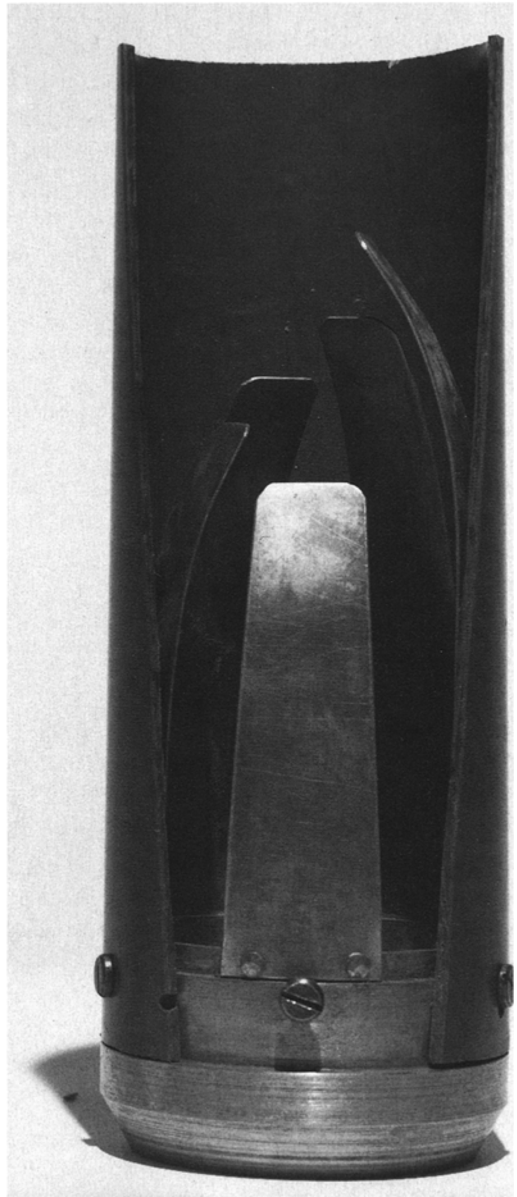

Fig. 4. Reusable machined core-catcher/cutting-edge assembly. Core barrel is 7.6 cm inside diameter.

The only significant modification to the core head involves reinforcement to reduce fracturing from driver impact. Double wall thickness is achieved by gluing a coupling to the top of the core head and cutting off the excess material (Fig. 1). Care must be taken in ensure the cut is close to 90° in order to prevent driver impact from concentrating at one point on the core head. Two attachment bolts serve to centre the main line and further ensure an even impact. In the event that a fracture develops in the core head, the equipment can be salvaged by cutting the pipe below the fracture and redrilling the bolt holes for the main line attachment. A minor simplification of the core head uses a flared or 'bell' end for the core barrel attachment rather than a coupling (Fig. 1). In either case, the inside of the bell end or coupling requires minor sanding to prevent the core head and barrel from binding during core removal.

Materials

It is important to ensure that the PVC pipe used for the core head and core barrels is a 'high strength' variety manufactured to exceed building standards. In Canada and the United States, Scepter® pipe is available and stands up well to driving impact. Lower grades of PVC pipe should be avoided as they shatter easily. Sheet aluminum was found an unsatisfactory material for the simple core catchers as core loss occurred when the fingers folded out during core retrieval. The use of 22 gauge galvanized sheet metal for core catchers minimizes this possibility. A high-strength rope is required for the main line due to the force required for core retrieval (11 mm climbing ropes are ideal because of their strength and ease of management). Unless the rope is a 'static line', however, rope stretch will need to be accommodated by placing an ice-screw anchor several meters from the hole. It is crucial that a static line is used for the driver line, particularly in deep water where rope stretch can be significant. Alternatively, plastic coated steel cable lines have been used for the driver and main lines (P. T. Davis, pers. commun, 1992).

Details of operation

The first step in coring involves drilling a hole in the ice pack. The apparatus described here will fit through a 15.25 cm diameter hole. Extensions for an ice auger are essential in some areas. Ice pack thicknesses in excess of 2.5 m have been encountered in alpine sites in British Columbia and the Canadian Arctic.

Adding a small weight to the core head (Fig. 1) allows it to also be used as a sounding device. Water depth should be marked directly on the main line using a device that pinches the rope (such as a paper clip) and will not slide on wet and frozen rope . The length of core barrel (3 or 6 m) is subtracted from the water depth and marked on the main line in a similar fashion. The core head-core barrel assembly can then be lowered through the water column until the core barrel is at or very near the sediment surface to ready the system for driving. The bottom of the core barrel should be at the sediment surface when the first marker on the main line reaches the water surface.

Feeding the main and driver lines from spools should be avoided as line twists can cause tangling. Fairly loose 'over the shoulder' coils generally work well for transportation and uncoiling. To minimize tangling, both lines should be uncoiled into separate piles so that the lines feed freely from the top of the piles when the corer is lowered through the water column.

The initial part of the driving process is critical. Care must be taken to ensure that the system drives vertically. This is accomplished by starting with small driver taps while exerting sufficient tension on the main line to keep the system vertical. During this phase, penetration should occur in small increments (<3 cm). The procedure is analogous to 'setting a nail' in carpentry where a few small taps are required before driving hard. Once the core head and core barrel assembly is firmly set into the surficial sediment, the driver is allowed to free fall about 2 m for each subsequent impact. Progress can be monitored by the rate of main line descent. Slight tension on this line is required during driving to guide the driver to the centre of the core head. When firm sediment is encountered, progress will slow to <1 cm per impact and the driver will start to 'double bounce' on the core head. The bouncing impacts are transmitted up the rope and are easily felt on the main line. If no progress is made after about thirty impacts, full penetration may be assumed. At this point, three or four bounces of the driver can be detected and the time between bounces noticeably increases. Continued hard driving under these circumstances may result in core-head fracture.

During driving, the top marker on the main line arriving at the water surface indicates when the top of the core barrel reaches the sediment-water interface. This, however, does not necessarily indicate that the core barrel is full. In all coring operations to date, the length of recovered core, to a varying extent, has been less than both the length accounted for by the main line and the depth of the mud line on the outside of the core barrel. This phenomenon has been noted in other coring systems (e.g. Wright, 1980) and may be due to: 1) the loss of core from an ineffective core catcher, 2) the compaction of sediment during driving, or 3) the friction of sediment entering the core barrel overcoming the strength of the sediment resulting in penetration without sediment actually entering the core barrel. The first possibility can be eliminated because, in several situations where this discrepancy has been large, the mud line on the inside of the core barrel has been only a few centimetres above the recovered surficial sediments. Although compaction cannot be ruled out, the absence of water-escape structures in recovered core suggests that the third possibility may be the most likely cause of the problem. Regardless of its origin, the severity of this problem varies considerably between sediment type. Once one core is recovered from a given lake, the degree to which a core can be 'overdriven' in order to fill the core barrel can be roughly estimated.

If it is determined that more than 3 m of sediment is present, assembly of a 6 m core barrel is necessary. Two 3 m core barrels are easily connected by joining a regular end and flared or 'bell' end with PVC glue. This connection should be reinforced with about ten 0.32 cm × 0.96 cm sheet-metal screws that require 0.16 cm guide holes. In this situation, the one-way valve is inserted at the top of the upper barrel and the 0.95 m support hole in the lower barrel is covered with duct tape. The driving procedure for a 6 m core barrel is the same as for a 3 m core described above.

When the driving process is considered complete, the driver is hauled to the surface and removed from the main line. An ice screw is then inserted into the ice pack to serve as an anchor for the pulley system, providing the mechanical advantage required to lift the core from the sediment (Fig. 3). Ice screws, carabiners (snap links), slings, and pulleys are common pieces of climbing equipment that are ideal for use in the removal system. Also, replacing the prussik knot (Fig. 3) with a climber's ascending device significantly simplifies the removal procedure.

In areas of high snowfall, a thick layer of slush may be present on top of ice surface that is insulated from freezing by the snowpack. Under these conditions, placement of an ice screw may be difficult. An alternative and equally effective anchor can be achieved by simply burying a pair of skis in a snow trench constructed perpendicular to the main line. In many cases, extra pulleys are required to increase the mechanical advantage necessary to retrieve the cores.

Once free of the bottom sediment, the core head and barrel are hauled to the surface and a 80 cm length of steel rod is inserted through the support hole at the top of the core barrel. The core barrel can then rest safely on the ice surface while the core head is removed. At this point a small weight on a fishing line is used to determine the depth to the sediment surface inside the core barrel. The core barrel is then raised to this level and a hole is drilled slightly above the sediment surface to allow water drainage. A battery hand drill is very convenient for drilling holes but a manual drill is sufficient and more reliable in the field. The entire core can then be removed taking care to keep the top of the core barrel at a higher level than the base.

If more than 3 m of core have been recovered, the core barrel is hauled to the surface, the core head removed, and water drained as previously described. The top 3 m core barrel is then raised above the ice surface and a second support rod is inserted through the duct tape covering the support holes in the top of the lower core barrel. This disturbs sediment near the lower support hole but removes the risk of losing the entire lower core section. The 6 m core barrel can now rest on the lower support rod. A cut is made with a hacksaw above the lower support and a piece of sheet metal is inserted into the cut. The upper core barrel is then removed using the sheet metal to prevent sediment loss. The lower 3 m of core is then removed as described above.

During winter coring operations in remote areas, preventing the cores from freezing may not be possible. Once frozen, however, the risk of further disturbance during transportation is eliminated. Generally, the cores are left overnight on the ice surface to freeze and subsequently cut into convenient lengths for transportation. PVC end caps are ideal for sealing the cut ends and can either be glued or taped in place. In situations where temperatures are not cold enough to freeze the cores, sediment disturbance is minimized by gently transporting the core sections vertically. Finally, the core sections are labelled with an indelible marker immediately after cutting.

Core splitting

Three general techniques have been used for core splitting: splitting with a thin wire, cutting with a band saw, and cutting with a high speed diamond rock saw. The most satisfactory results were obtained by using a high speed rock saw. This method quickly and easily cuts through fine grained organic sediments as well as large clasts. The cores are cut while completely frozen and the surface washed immediately after splitting. Photographing core as soon as possible after the cores are split is desirable as significant changes in sediment colour occur rapidly with oxidation. Splitting with a piano wire requires the core barrel to be cut on opposite sides with a rotary hand saw or table saw. Once the core has completely thawed, the wire is pulled through the sediment and the two halves gently pried apart. Major difficulties arise when large clasts or organic fragments are present. Further, particularly with inorganic sediments, this method can obscure fine details of sedimentary structure. This loss of detail may be circumvented by cutting the core while frozen with a band saw and washing off the smeared surface. However, the main drawbacks of using a bandsaw are that two blades are usually destroyed for each split core and that sediments tend to work into many internal areas of the saw.

Examples of recovered core

Several examples of recovered core are presented in Fig. 5 to demonstrate the capabilities of the system and exhibit degrees of core disturbance. All cores were recovered using a simple galvanized basket core catcher (which provides a relatively blunt cutting edge) and without the use of a piston. Presumably, sediment disturbance would have been reduced by using a piston or the reusable core-catcher/cutting-edge assembly.

In many cases, particularly with sediments of relatively high organic carbon content (gyttja), core disturbance is minimal. The laminated gyttja in Fig. 5a and upper sections of Figs 5b and 5c exhibit ideal core recovery with very little core disturbance. Mazama tephra (*ca* 6800 yrs BP) is present in Fig. 5a. In cores containing both high and low organic-carbon sediment, core disturbance in the form of down warping along the core edge (coning) is primarily restricted to the underlying light grey inorganic sediment (Fig. 5b, 5c). The lower inorganic section of Fig. 5c shows both moderate coning and disturbance related to subaqueous slumping. Evidence for mass movement in these sediments is also apparent on seismic records from the site (Reasoner & Rutter, 1988). The contact between dark organic and underlying light grey inorganic sediments in 5b and 5c has been radiocarbon dated at *ca* 10 100 yrs BP (Reasoner & Rutter, 1988). Extreme coning has occurred in lacustrine sediments of low organic-carbon content (Fig. 5d) and in marine sediments (Fig. 5e). Figure 5f shows an example of a core

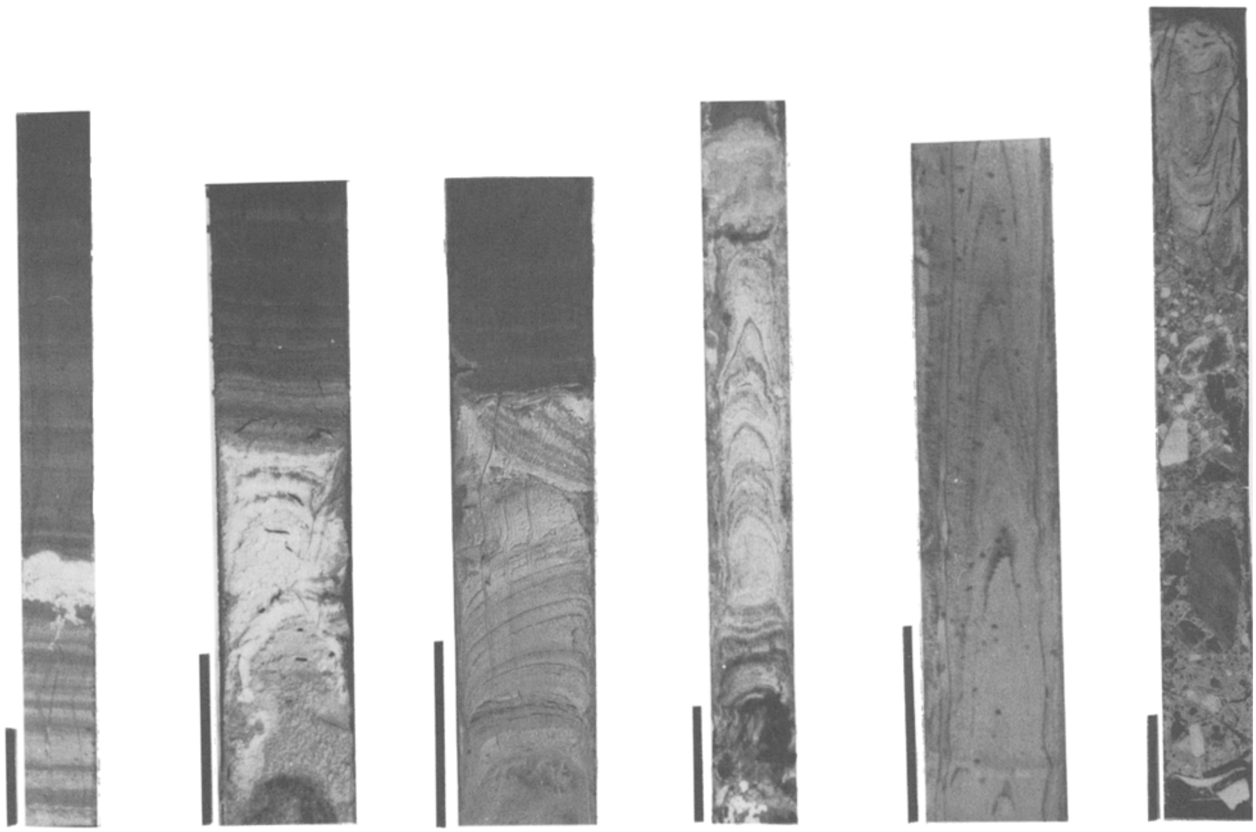

Fig. 5. Examples of recovered core: 5a. minimal coring disturbance of laminated gyttja containing Mazama Tephra (*ca* 6800 yrs BP); 5b and 5c undisturbed dark gyttja overlying light grey inorganic sediment that display moderate coning; 5c. the underlying light grey inorganic sediment show both moderate coning and disturbance from mass movement; Examples of severe coning in laminated inorganic 5d. lacustrine and 5e. marine sediments; 5f. massive 'basal' diamicton with a portion of the core catcher visible at the base. All cores are 7.6 cm in diameter. Scale bar to the left of each core represents 10 cm.

that penetrated massive 'basal' diamicton. In circumstances where 'basal' diamicton is recovered in multiple cores from a single lake basin, a high degree of confidence can be placed on the assumption that the cores represent the entire post glacial record.

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References

Beaudoin, A. B. & M. A. Reasoner, 1992. Evaluation of differential pollen deposition and pollen focussing from three Holocene intervals in sediments from Lake O'Hara, Yoho National Park, British Columbia, Canada: intra-lake variability in pollen percentages, concentrations and influx. Rev. Palaeobot. Palynol. 75: 103–131.

Gilbert, R & J. Glew, 1985. A portable percussion coring device for lacustrine and marine sediments. J. Sediment. Petrol. 55: 607–608.

Lemmen, D. S., 1990. Glaciomarine sedimentation in Desraeli Fjord, High Arctic, Canada. Mar. Geol. 94: 9–22.

Nesje, A., K. Søgnen, A. Elgersma & S. O. Dahl, 1987. A piston corer for lake sediments. Norsk geogr. Tidsskr. 41: 123–125.

Nesje, A., 1992. A piston corer for lacustrine and marine sediments. Arctic and Alpine Research, 24: 257–259.

Reasoner, M. A., 1986. An inexpensive, lightweight percussion core sampling system. Géographie Physique et Quaternaire, XL 2: 217–219.

Reasoner, M. A. & N. W. Rutter, 1988. Late Quaternary history of the Lake O'Hara region, British Columbia – an evaluation of sedimentation rates and bulk amino acid ratios in lacustrine records. Can. J. Earth Sci. 25: 1037–1048.

Wright, H. E., 1980. Cores of soft lake sediments, Boreas 9: 107–114.