A Portable Core Sampler for Lake Deposits

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ABSTRACT

A pneumatically operated core sampler is described which is easily portable and may be used by two men from a rowing boat. The apparatus takes an undisturbed sediment core 6 m long and is substantially independent of water depth up to a limit of some 250 m. The hydrostatic pressure operating on a cylindrical anchor chamber embedded in the sediment is used to hold the apparatus in contact with the bottom while the coring tube is driven downwards by compressed air. On completion of the coring operation, the anchor chamber is automatically filled with air, the coring tube is extracted from the sediment, and the apparatus brought to the water surface by the buoyancy lift. The use of heavy weights and the associated lifting tackle is therefore avoided.

INTRODUCTION

The sediments at the bottom of a lake contain a record of the biological and chemical changes which have taken place in the system throughout the period of sedimentation. It is therefore important that samples of such sediments should be obtained for study without disturbing their sequence. A number of samplers which achieve this objective have been described, all of which suffer from some disadvantage when applied to limnological work. The Kullenberg and the Jenkin samplers (Kullenberg 1947, Jenkin et al., 1941) both use heavy weights to drive the apparatus into the sediment, thus necessitating the use of heavy lifting tackle and relatively large vessels or floating platforms, neither of which is normally available on the majority of lakes. The field of limnological operation of these instruments is therefore limited. The difficulties of transportation and handling inherent in the Kullenberg and Jenkin samplers were overcome by Livingstone (1955) who described a piston sampler which is similar in principle to the Kullenberg sampler, but is pushed into the sediment by hand by means of a long jointed rod. While the apparatus obtains very satisfactory cores, great difficulty is found in operating in water depths greater than 20 meters because of the flexibility of the rod used to push the sampler into the sediment even when the rod is stiffened by a casing pipe. This depth limitation is serious when samples are to be taken from deep lakes, since it is well known that the shallow water sediments of such lakes are not typical and may differ widely from the sediments in the deep water of the same basin. It was therefore desirable to devise an apparatus which, while being readily portable, could be used in any depth of water likely to be encountered in the lakes of the English Lake District (up to 80 metres). This objective was achieved by means of the apparatus here described.

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GENERAL DESCRIPTION OF APPARATUS AND MODE OF OPERATION

An outline of the apparatus is shown in Figure 1. A is a 20-ft length of stainless steel tubing 3 in. external diameter. The lower end of this tube is fitted with a flange which is bolted onto the upper surface of the drum G. The latter consists of a cylinder of sheet steel closed at the upper end by a steel plate. This cylinder is 18 in. in diameter and 4 ft high and open at the lower end, and is subsequently referred to as the anchor chamber.

Inside the stainless steel tube is the coring
tube. This tube is inserted at the upper end into the piston C which closely fits the bore of the tube A. In the lower end of the coring tube B is a piston F. This piston is attached by means of the narrow tube D to the plug L which closes the upper end of the stainless steel tube A, so that the piston is unable to move downwards in relation to A. The narrow tube D passes through a sliding pressure seal in the centre of piston C so that this piston and the coring tube may move downwards, the coring tube passing through a clearance hole in the centre of the upper plate of the anchor chamber.

In operation an air pressure hose is attached to the tube H which passes through the plug L, and a plastic hose P is connected to the tube H which passes into the anchor chamber. The apparatus is lowered by means of a rope fastened to a chain bridle at M until the lower part of G comes into contact with the sediment. While a small constant tension is kept on the rope to ensure that the instrument remains vertical, water is pumped from the anchor chamber through the hose P. As water is withdrawn, the hydrostatic pressure pushes the anchor chamber into the sediment until when mud emerges from the hose the upper plate of G is level with the sediment surface. The upper end of the hose P is now closed, and the anchor chamber now embedded in the sediment is capable of resisting a considerable upward force because of the hydrostatic pressure which comes into play as soon as any such force is applied. Compressed air is now admitted through E. The pressure in the space Q drives the piston and coring tube downwards until the lower end of the piston C is stopped by the flange K (Fig. 3) on the upper plate of G. When the piston C passes the point R, the compressed air behind C passes through the hose I into G. The entry of air under pressure lifts the anchor chamber out of the sediment with considerable force. (Since the area of the upper plate of G is 260 in.\(^2\) an excess of 10 lbs/in.\(^2\) over the external pressure exerts a lifting force of about 1 ton.) This initial lift also extracts the coring tube, since C is resting on the upper plate of G. When the anchor chamber is full of air and it has risen almost clear of the sediment surface, the buoyancy lift of G completes the extraction and lifts the apparatus to the water surface. The buoyancy of the anchor chamber when full of air is equal to an uplift of some 450 lbs which brings the apparatus to the surface with considerable violence. This violence is moderated by the release valve at J (described later) which allows most of the air to escape during the ascent when the core tube has been completely extracted. The apparatus is then taken ashore and the core extracted hydraulically into suitable containers. The manner of extraction of the core is described in the section on handling the apparatus.

CONSTRUCTIONAL DETAILS

The tube A in Figure 1 is of stainless steel 20 ft long, 3 in. external diameter, wall thickness \(\frac{3}{16}\) in. It is fitted with a welded flange at the lower end which is 6 in. in diameter, \(\frac{3}{8}\) in. thick, and drilled with 4 equally spaced clearance holes to take the \(\frac{3}{8}\) in. bolts (G\(_4\) in Fig. 3). The inside of the tube is polished. The upper end of the tube A is closed by a “pickle-bottle” seal L in Figure 1. Details of this sealing arrangement are shown in Figure 2. L\(_1\) and L\(_2\) in Figure 2 are brass discs which are a sliding fit into the bore of the tube A and respectively \(\frac{3}{16}\) in. and \(\frac{3}{4}\) in. thick. Both discs are drilled centrally with clearance holes for the brass tube D (36 in. external diameter.) L\(_3\) is a rubber disc of the same diameter \(\frac{3}{4}\) in. thick and drilled in the center to fit the tube D. Two diametrically placed \(\frac{3}{8}\) in. bolts (one of which is shown dotted at L\(_4\)) pass through clearance holes in L\(_3\) and L\(_2\) into blind tapped holes in L\(_1\). The tube L\(_5\) which is threaded to take a standard \(\frac{3}{8}\) in. gas nipple at L\(_6\) is brazed into L\(_2\), and the lower end of the tube is turned down to pass through a clearance hole in L\(_1\) and L\(_2\). This assemblage is anchored to the stainless steel tube by 4 equally spaced radial OBA screws (L\(_7\)) which pass through the wall of tube A into threaded holes in L\(_7\). Two of these screws serve to attach by means of two small steel plates
Fig. 1. Diagrammatic cross section of the complete apparatus, not to scale. Letters referred to in the text.

Fig. 2. Details of the sealing components of the upper end of the apparatus and of the driving piston. Letters referred to in the text.
\( \frac{1}{8} \) in. thick (not shown) the chain to which
the lowering rope is fastened to the appara-
utus. When the assembly has been fixed
into the tube \( A \) by the screws \( L_3 \), tightening
the bolts \( L_4 \) compresses the rubber disc and
produces an effective pressure seal. The
narrow tube \( D \) is 20 ft 4 in. long, of \( \frac{3}{8} \) in.
external diameter brass with walls \( \frac{1}{16} \) in.
thick. This was built from shorter lengths
with brazed spigot joints carefully smoothed
on the outer surface. The joints should be
strong since a substantial load in tension
must be carried by \( D \) during hydraulic
extraction of the core as is explained later.
\( D \) is threaded at the top for the 1\( \frac{1}{2} \) in.
which protrude through the plug \( L_5 \), and is
prevented from moving downwards in rela-
tion to \( L \) by the nut \( L_9 \). The upper end of
\( D \) is fitted with an adaptor \( L_7 \) of hexagon
brass screwed to take a standard \( \frac{1}{4} \) in. gas
nipple. \(D\) passes axially down the length of the apparatus to the piston \(F\) which is screwed onto its threaded lower end. \(D\) is pierced at the lower end just above \(F\) by three \(\frac{3}{8}\) in. holes (\(d\) in Fig. 4) spaced as shown to preserve the strength of \(D\). The function of these holes is explained below.

The piston \(C\) in Figure 1 is shown in detail in Figure 2. \(C_1\) is a cylinder of brass which is a tight fit onto the outside of the upper end of the "Duralumin" coring tube \(B\). This cylinder is a sliding fit into the bore of tube \(A\) and is 5 in. long. The cylindrical brass plug \(C_2\) is a tight fit into the bore of \(B\) and is 3 in. long. \(C_2\) is drilled axially with a clearance hole for the tube \(D\).
$C_1$ and $C_2$ are pushed into place on the upper end of $B$ until the ends of all three are flush. This assembly is then locked in position by the insertion of 3 equally spaced OBA countersunk screws which pass radially through $C_1$ into $C_2$. One of these screws is shown at $C_3$ in Figure 2.

The scaling components of the piston $C$ are also shown in Figure 2. $C_4$ is a disc of rubber $\frac{3}{8}$ in. thick, its diameter equal to the bore of $A$ (2½ in.) with a central hole fitting the outside diameter of $D$. $C_5$ is a similar disc of leather $\frac{1}{4}$ in. thick. $C_6$ is a neoprene cup washer 2½ in. in diameter, sealing the bore of $A$ from pressure from below. $C_7$ and $C_8$ are two small neoprene oil seals arranged back to back so as to produce a sliding seal on $D$ which is effective against pressure applied either from above or below. The brass washer $C_9$ is $\frac{1}{4}$ in. thick, 2½ in. in diameter, drilled in the centre to take $D$ and shaped as shown in Figure 2 to accommodate and support the neoprene seals $C_6$, $C_7$, and $C_8$. $C_9$ is a plain brass washer 2½ in. in diameter drilled centrally to clear $D$. These components are assembled as shown in Figure 2 and held in position by two 2 BA screws $C_{10}$ which pass through the assembly into tapped holes in $C_2$. With the piston assembly in place inside $A$ the screws $C_{11}$ are tightened to compress the discs $C_4$ and $C_5$ against the bore of $A$, until the piston is sufficiently tight in the bore to prevent the coring tube sliding down under gravity when the apparatus is suspended vertically. It should be just comfortably possible to push the piston down the bore of $A$ by hand.

The coring tube $B$ is a 20-ft length of 2 in. external diameter, 3/16 in. wall “Duralumin” scaffold tubing. This tube was smoothed internally before assembly, in order to ensure the sealing of the piston $F$ (Figs. 1 and 3). The tube is held at the upper end by the piston $C$, which lies initially in contact with the upper plug $L$, and passes co-axially down the length of the tube $A$ to protrude approximately 2 in. beyond the flanged lower end of $A$, passing through a central clearance hole in the upper surface of the anchor chamber $G$ (Fig. 1) when the apparatus is assembled.

The lower end of $B$ is ground to a cutting edge (Fig. 3). The piston $F$ (Fig. 3) is screwed to the lower end of tube $D$ and fits the bore of $B$. $F$ occupies the position shown in Figure 3 in relation to $B$ when the apparatus is ready for operation. Approximately 12 equally spaced radial $\frac{3}{8}$ in. holes are drilled through the wall of $B$ (b in Fig. 3) at a distance of $1\frac{1}{2}$ in. above the lower edge of $B$ so that the holes lie above the piston $F$ when the coring tube is fully home in $A$. These holes allow water to enter the bore of $B$ when the apparatus is lowered into the water, and prevent the increasing hydrostatic pressure from pushing $F$ up the bore of $B$, which would be likely to damage the tube $D$ (apart from other ill effects). The inside edges of these radial holes are carefully smoothed with carborundum paper to avoid damage to the cup leather of piston $F$ when the coring tube slides over $F$ during operation.

The piston $F$ is made from a rod of “Duralumin” which is a sliding fit in the bore of $B$. It is drilled and tapped centrally with a blind hole on the upper surface to take the screwed lower end of $D$. The leather cup washer $F_1$ is a tight fit against the inside wall of $B$ and is held in place by the washer $F_2$ and the two screws $F_3$ which pass through $F_2$ and $F_3$ into the duralumin rod.

The flanged lower end of $A$ is bolted down to the upper surface of the anchor chamber by four equally spaced $\frac{3}{8}$ in. bolts $G_1$ (Fig. 3). The rubber gasket $G_2$ ensures an airtight joint.

Six inches above the flange on $A$, at $R$ in Figures 3 and 4, the wall of the stainless steel tube is drilled to take a brass tube 1 in. long of $\frac{3}{4}$ in. external diameter and $\frac{1}{8}$ in. internal diameter which is brazed into $A$. Any protrusion produced in the bore of $A$ is carefully removed and smoothed to allow the piston $C$ to pass freely. This short tube is connected by a length of flexible reinforced pressure hose $I$ in Figure 3 to a similar short brass tube inserted and brazed through the upper surface of the chamber $G$ at $G_3$ in Figures 3 and 4. The flexible hose is secured to the brass tubes at both ends by hose clips.

Figure 3 shows the relative positions of the components at the lower end of the
apparatus before a core is taken. Figure 4 shows this position after the coring tube has been driven into the sediment by the movement of the piston C down the length of the tube A after compressed air has been admitted through L8 (Fig. 2). When the upper end of C passes the point R in Figure 4, compressed air is blown through I into the anchor chamber G. The air and water which occupied the bore of the coring tube B before the sample was taken are driven through the holes (d, d, d, in D) up the bore of D and out of the upper end at L7 (Fig. 2). The bore of B below F now contains the sediment core. The lower surface of the piston C now rests on the upper plate of G at K (Fig. 4), so that as G rises from the sediment under the influence of the injected compressed air, the core tube is extracted with it.

The anchor chamber is constructed from .05 in. steel sheet rolled to form a cylinder and welded at the seams. The cylinder is 18 in. in diameter and 4 ft long, the upper end of which is closed by a circular steel plate $\frac{3}{8}$ in. thick, 18 in. diameter, welded into position. All the welded seams must be air-tight. The lower end of the chamber is left open, but the wall at the lower end is strengthened by welding on a hoop of $\frac{3}{8}$ in. thick steel 1 in. wide.

In the centre of the upper plate of G a clearance hole is cut to allow the coring tube to pass through it (see Figs. 3 and 4). The four $\frac{3}{8}$ in. bolts used to secure the flange of tube A to the top of the drum are passed through holes cut in the plate of G. The heads of these bolts are welded onto the underside of the plate. A steel tube (U in Fig. 1) 6 in. long, $\frac{3}{4}$ in. external diameter, $\frac{3}{8}$ in. wall, is inserted through the plate and welded into position. The hose P used in pumping water from the drum is connected to this tube and secured with a hose clip. A second steel tube S (Fig. 1) 1$\frac{3}{4}$ in. external diameter, $\frac{3}{8}$ in. wall, is passed through the top plate of the chamber so that it protrudes 3 in. above and 9 in. below the top plate. The upper end of S which is machined square, is closed by a rubber disc T cemented into a steel cup which is welded to the steel bar U ($\frac{3}{4}$ in. X $\frac{3}{16}$ in. flat bar). The post W of $\frac{3}{4}$ in. square section bar welded to the edge of the anchor chamber plate, supports the arm U in a fork cut in the upper end of W, and U pivots about a $\frac{1}{4}$ in. bolt passing through the fork at X in such a way that the rubber disc may fit squarely on the upper end of S when U is pulled down by the powerful spring V. The outer end of U has a cylindrical piece of steel approx. 1 in. long welded on, the latter being threaded to receive the tubular steel extension arm Y 2 ft long, which may be detached for convenience in transport. In the field a light chain is shackled to the extension at Z. The chain is 15 ft long and is attached at the other end to an iron disc weight approximately 6 in. in diameter by 1 in. thick which weighs approximately 6 lbs. The spring V is chosen so that a downward pull is exerted on T equal to about 40 lbs. This would require the pressure within the anchor chamber to reach 50 lb/in.$^2$ above hydrostatic pressure before the valve would open. Such a pressure is unlikely to be reached in practice since it would correspond to a lifting force on the chamber of about 5 tons which is probably much greater than the force required to extract the coring tube from the sediment.

When the apparatus is being lowered into the water, the weight is allowed to hang freely from the chain so that the valve is open until the weight reaches the bottom, when V pulls T into contact with the upper end of S. The valve remains closed until, after taking a core, the apparatus is rising clear of the sediment. It opens when the weight is lifted clear of the bottom, permitting air to escape through S until the water surface inside the anchor chamber has risen to the level of the lower end of S. The remaining air then brings the apparatus to the water surface reasonably gently.

**ADDITIONAL EQUIPMENT**

Sufficient air pressure hose is required to reach the bottom in the deepest lake in which it is desired to operate. The air hose is of the type used on gas welding equipment, $\frac{1}{2}$ in. external diameter with $\frac{3}{16}$ in. bore and with canvas reinforced rubber walls.
This hose has a working pressure of about 400 lbs/in.², but would probably stand a greater pressure before bursting. It is convenient to have the hose in sections of 30 m, the sections being coupled by standard gas nipple connections. One end of the hose is fitted with a nipple and nut for connection to the apparatus at L₈ (Fig. 2), and the other end has a suitable fitting for connection to a compressed air cylinder. A similar length of P.V.C. garden hose of ¾ in. bore is required, which is connected to the tube H in Figure 1 and secured by a hose clip. A rope of ½ in. diameter hemp or nylon is attached by means of a chain bridle to steel lugs fastened to the upper end of the apparatus by two of the radial screws holding the upper plug at J₁₃ in Figure 2.

Water is pumped from the anchor chamber through the P.V.C. hose. A convenient method of pumping the water out of the chamber is simply to inject air into the P.V.C. hose about 6 ft. above its connection with G. When air is injected into the water column in the hose, the density of this column is reduced in relation to the similar column outside the hose, and water is forced out of the anchor chamber and up the hose. Quite fast pumping rates can be achieved using this method which removes the necessity of carrying any pumping equipment. In practice air is injected into the P.V.C. hose through a stainless steel hypodermic needle. This should have a bore of not less than ⅛ in. and should be bent at right angles about ¼ in. from the point. The syringe end of the needle is securely fastened into the end of a rubber pressure hose which should be about ¾ in. bore and strengthened by external braiding to stand a pressure at least equal to the hydrostatic pressure at the greatest operating depth. The point of the hypodermic needle is inserted into the P.V.C. hose 6 ft above the anchor chamber, so that the ¼ in. length of the needle which is bent at right angles lies within the P.V.C. hose. The rest of the needle is laid alongside the P.V.C. hose and taped into place with water-resisting polythene self-adhesive tape. The rubber hose from the needle is taped at intervals to the P.V.C. hose so that the two hoses may be handled as a unit. The upper end of the rubber hose is fitted with a suitable coupling for connection to the compressed air cylinder. It is convenient to take compressed air directly from the cylinder (normal commercial cylinders are used), without a reducing valve, since the ordinary reducing valve is not capable of giving a high enough pressure. The pressure and flow of air is controlled by the cylinder valve itself. A suitable pressure gauge reading up to some 400 lbs/in.² is required, and care should be taken not to subject the gauge to the full cylinder pressure.

For hydraulic extraction of the core from the coring tube a hand operated water pump is used. The type of pump known as a "stirrup" pump which was issued to householders during World War II for fighting incendiary bombs is suitable. This pump is capable of producing a pressure of about 200 lbs/in.² which is adequate. A short reinforced hose fitted with standard nipple for attachment to the upper end of the tube D at L₇ (Fig. 2) is connected to the pump.

**OPERATION AND HANDLING**

Given reasonable weather conditions, the apparatus can be handled by two men working from an ordinary rowing boat. It is seldom necessary to anchor the boat, since, when the drum has been pumped into the sediment, the apparatus is firmly attached to the bottom and serves as an effective anchor. It is convenient, however, to have a second boat in attendance which is used to tow the operating boat into position to avoid the inconvenience of operating oars or outboard motor in the same boat as the corer. The apparatus is carried in the boat lying fore and aft with the anchor chamber protruding over the stern. Before leaving the shore, the hoses and rope are attached to the apparatus, the air pressure hose at L₈ (Fig. 2) and the P.V.C. hose at H (Fig. 1). The hoses and rope are coiled into the boat. The upper end of the rubber hose which carries air to the hypodermic needle in the P.V.C. hose is connected to the compressed air cylinder. The boat is then moved to the site of operations. The extension arm of the release valve Y (Fig. 1) is screwed into
place, and the weight on the end of the chain is lowered into the water so that it is hanging freely. The apparatus is then slid over the stern and lowered by means of the rope while the hoses are payed out. As the apparatus is lowered into the water, the core tube is prevented from sliding downwards by the hydrostatic pressure acting on the leather seal C₈ (Fig. 2) apart from frictional forces. It is important that this seal is sound, otherwise with much USC the movement of the piston C may become sufficiently easy to allow the corer to move downwards prematurely under gravity. The apparatus is not heavy to handle under water since enough air is trapped in the anchor chamber and the tube A to provide a considerable upthrust. When the anchor chamber reaches the sediment sufficient tension is maintained on the rope to keep the apparatus vertical to the mud surface. Air is now injected into the P.V.C. hose by applying a pressure from the cylinder to the air line connected to the hypodermic needle. The pressure should be maintained above the hydrostatic pressure. When air is injected into the P.V.C. hose, pumping commences and the upper end of the hose should be held over the side of the boat. As water is pumped out, the anchor chamber gradually sinks into the sediment and sufficient rope should be payed out to allow this while a sufficient tension is maintained to ensure that the apparatus is vertical. Pumping is continued until traces of the flocculent surface mud appear in the effluent from the P.V.C. hose. The plate of the chamber is now level with the mud surface, the chamber itself being entirely submerged in the mud. (This point was checked by divers of the East Lancashire Subaqua Club, for whose help the author is grateful.) The pumping time varies between 5 and 15 minutes depending on the water depth. The deeper the water the more efficient is the pump. The apparatus is now very firmly attached to the bottom, since any attempt to withdraw it is opposed by the hydrostatic pressure acting on the plate of the anchor chamber. The actual force required to lift the chamber out of the sediment has not been measured, but an upper limit can be calculated. Assuming (erroneously) that the mud is incapable of flow, if the operating depth is 50 metres, the pressure on the top plate when the chamber begins to be withdrawn is equal to 6 atmospheres, so that with an area of 250 in.² the force required would be 22,500 lbs. This force would increase proportionally with depth. In practice, since the sediment is in fact capable of flow, the withdrawal force is likely to be much less than this calculated quantity but is nevertheless quite adequate to hold the apparatus in contact with the bottom while the core tube is driven into the sediment.

When pumping has been completed, the air hose to the injection needle is disconnected from the compressed air cylinder, and the upper end of the P.V.C. hose is closed either with a wide bore tap or by means of a plug held in place by a hose clip. The air pressure hose connected at L₅ to the apparatus is now connected to the compressed air cylinder, and air is admitted to maintain a pressure about 100 lb/in.² above the hydrostatic pressure. This air pressure acting on the piston C (Fig. 1.) drives the core tube into the sediment. When the core tube has been driven in completely, C passes the point R (Fig. 1) and a sudden fall in pressure is observed as the compressed air in A is released into the anchor chamber. The core tube is driven in rapidly, less than 1 minute normally being required. The flow of air is continued in order to fill the chamber and extract it from the sediment. This operation may take several minutes, the time required naturally increasing with the depth of the water. If a steady tension is kept on the rope, the apparatus will be felt to be slowly rising as the chamber is ejected. When the anchor chamber is full of air, the buoyancy lift completes the withdrawal of the core tube, and the apparatus is felt to be rising rapidly clear of the bottom. The air supply should be shut off and the rope should be hauled in at this stage in order to have as little slack as possible. When the release valve opens as the weight hanging from the valve arm rises clear of the bottom, the rate of ascent is checked and it should be possible to keep up with the rising apparatus by
humping in the rope. The apparatus usually surfaces almost horizontally, surrounded by air bubbles.

The apparatus should be prevented from sinking again (because most of the air in the chamber is lost at this stage) by again opening the compressed air cylinder and blowing air into the chamber. The rope should also be hauled in as quickly as possible. The apparatus should not be allowed to sink to any great depth after surfacing, since the hydrostatic pressure acting on the piston C tends to force the core tube back into A, which ejects part of the core from the lower end of the core tube. With a little practice the apparatus can be brought aboard the boat without much effort by judicious addition of air to the anchor chamber and manipulation of the rope. The corer is laid fore and aft in the boat, with the chamber about amidships and the core tube now extended lying on the stern. The hoses are taken aboard and the valve release weight hauled in. The boat is now taken ashore, and the apparatus laid on a suitable beach for extraction of the core.

To receive the core, 5' 6" lengths of trough are used. These may be made by splitting 2 in. internal diameter thin wall aluminium tubes lengthwise, or may be made from wooden planks joined at right angles to form a V-section trough. Four such lengths are required for each complete core. The end of the core tube is supported by placing a trough lengthwise under it, and supporting the trough on a wooden stand of a height slightly smaller than the radius of the anchor chamber. The air hose is disconnected from L8 (Fig. 2), and the hose from the hand water pump is connected at L7. The pump hose should be filled with water before connection to keep the volume of air in the system to a minimum. Water from a bucket is now pumped into the apparatus down the tube D (see Fig. 4). The water from D emerges through the holes d, d, d (Fig. 4) and into the space between pistons F and C. Since F is restrained from movement by D in tension, the pressure acting on C retracts the core tube into A, the core being simultaneously ejected as the core tube is retracted. This results in the core being left behind in the receiving trough as the core tube moves smoothly back into A. When the first trough is full the next trough is placed in position under the coring tube, and the supporting table is moved back toward the chamber by one trough's length. The troughs should be tightly held while the core tube is retracted so that they are not dragged along by the tube. Pumping is continued until the entire core has been collected in the four troughs and the core tube is again completely home in the tube A. This stage is reached when the pumped water is ejected from the radial holes in the end of the core tube (Fig. 3). The water pump is disconnected and the air pressure hose reconnected at L9. The apparatus is now in the starting position and ready to take another core.

The cores lying in the troughs are wrapped in cellophane secured by adhesive tape for transport to the laboratory.

**Operation in Shallow Water**

In waters 25 m or less in depth, there is insufficient time for the air release valve to function before the apparatus reaches the surface. This results in a somewhat violent ascent which may damage the apparatus, boats, or operators. In shallow water it is therefore advisable to operate rather differently. The release valve is not used at all and the extension arm and weight are not connected. The apparatus is lowered to the bottom in the usual way but before pumping begins a float is secured to the rope at the water surface (a 5-gallon oil drum is suitable). The anchor chamber is now pumped out and the apparatus descends drawing the float under the water surface. The float now supports the apparatus vertically and the operators may retire to a safe distance before driving the corer in. After completion of the coring operation the apparatus rises to the surface and may leap out of the water with the anchor chamber clear of the surface. The apparatus is now approached and prevented from sinking as previously described.

**Consumption of Compressed Air**

The amount of air consumed depends on the depth of water in which the apparatus is
operated. The deeper the water the fewer the cores which may be taken with a single air cylinder. In intermediate depths of some 50 m a standard 240 ft³ cylinder will take 3 or 4 cores. The cylinders could of course be replaced by a small portable air compressor capable of producing sufficient pressure for the operating depth required.

When working away from the laboratory, it is desirable to have a spare cylinder on hand in case of need.

TRANSPORT OF APPARATUS

For convenience in transport the anchor chamber is removed from the end of the stainless steel tube, the hose I (Fig. 3) being disconnected. The stainless steel tube with core tube inside can easily be transported on a small vehicle, lashed either alongside with suitable supports at the ends, or on the roof of the vehicle.

RESULTS

The cores obtained are cylindrical 1½ in. in diameter and 19 ft 6 in. (595 cm) long. There is no evidence of any distortion of the sediment strata, and the varves of the glacial clays lie quite flat in those localities where the sediments themselves have not been distorted by slumping on underwater slopes. The cores are large enough to allow relatively big samples to be taken for analysis from a narrow depth zone. Quite large pieces of organic debris, wood fragments, hazel nuts, and leaves are found in the cores which should enable sufficient carbon to be collected from a given depth to allow radiocarbon dates to be obtained.

The ease of transport and handling enables cores to be obtained from those lakes which are too remote for the Jenkin corer to be used and too deep for the Livingstone corer.

The length of the core in the present apparatus is limited to approximately 6 m by the length of the tube B. The apparatus could probably be made longer, but handling difficulties would perhaps become serious if the length were extended much above 9 m.

The depth of water in which the apparatus will operate is limited by the air pressures required to equal hydrostatic pressure. If one allows a practical limit of pressure at about 500 lb/in.² with the present hoses, this would limit the operating depth to about 280 m allowing for an operating pressure 100 lbs/in.² above the prevailing hydrostatic pressure. Such pressure limitation could be overcome by hydraulic operation of the apparatus rather than pneumatic operation, but the buoyancy lift of the drum would be lost and other arrangements would have to be made to lift the coring tube out of the sediment. It seems unlikely however that the present apparatus would be used in very great depths of water where a fairly large vessel would normally be available, permitting the Kullenberg corer to be used with advantage.

The advantages of the present apparatus lie in ease of transportation and speed of operation. It is possible in a day's expedition to visit the more remote lakes of this area and obtain several 6 m cores. When working on Windermere, with the apparatus at hand it is possible to obtain a deep water core almost as quickly as one would obtain a deep water sample.

SUMMARY

The sampling apparatus described has been used to obtain sediment cores 6 meters in length from relatively deep lakes. It may be handled by two men working from a rowing boat and is easily transported from lake to lake. The sampling tube is driven into the sediment and extracted pneumatically without the use of the heavy weights needed to operate the Kullenberg and the Jenkin samplers.

REFERENCES

