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DEPARTMENT OF MINES AND TECHNICAL SURVEYS

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QUATERNARY PALYNOLOGICAL SAMPLING TECHNIQUES OF THE GEOLOGICAL SURVEY OF CANADA

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R. J. Mott

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R. J. Mott

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ABSTRACT

The methods used in sampling bogs including the sampling devices used, the techniques of coring, and the handling of samples are outlined. One of the earliest devices developed, the Hiller peat borer, is still the best device for sampling fibrous bog deposits. A moveable piston device of large size has been developed for sampling the lowermost organic materials above inorganic sediments to obtain suitable samples for radiocarbon dating. Another moveable piston device, the Davis sampler, is much smaller in size and is useful for sampling very compact sediment.

Lake bottom sampling utilizes more and varied equipment and different problems are encountered. A suitable stable raft, casing, and the special techniques used are discussed. Lake deposits can be sampled for reconnaissance purposes using a gravity corer, but this device is not suitable for detail sampling for palynological purposes. The Brown sampler, developed specifically to sample across the mud-water interface, and the Livingstone sampler for sediments beneath, are invaluable tools for this purpose.

Augers for sampling surficial deposits and coring devices, such as the Courtemanche permafrost corer and the Sipre ice-corer, used successfully in sampling in permafrost, are discussed briefly.

QUATERNARY PALYNOLOGICAL SAMPLING TECHNIQUES OF THE GEOLOGICAL SURVEY OF CANADA

INTRODUCTION

The sampling of bogs, and in recent years the sampling of lake bottom sediments, for palynological studies by the Geological Survey of Canada has resulted in the acquisition of several sampling devices and other related equipment as well as in many refinements to sampling techniques. Unlike bog sampling where a minimum amount of equipment is required, lake sampling requires a large amount of varied equipment. This disadvantage is offset by the superior quality of the samples and the more complete record usually available in lakes.

For palynological studies the complete sequence of sediments in a deposit should be sampled. Samples free of contamination and as little disturbed as possible are the main objectives. As only small amounts of material are required for pollen analysis the sampling devices need not be large in diameter. If, however, samples are required for radiocarbon dating or for study of macrofossils the larger amount of material needed can be obtained by repeated coring or by using devices of larger diameter.

Two basic types of samplers have been developed for sampling unconsolidated sediments. One type utilizes a tube that is filled as it penetrates the sediment. The other penetrates the sediment before sampling and takes a sample from alongside. Some problems are encountered with these simple devices such as compression, distortion, and loss of core in the case of the tube-type sampler and complete disturbance of the core in the second type. Contamination is also a serious factor with some devices. Numerous innovations and modifications of these basic designs have improved the quality of the core, increased the depth of penetration, and increased the amount of core recovered.

This paper will examine in detail only those devices that have been used by the Pleistocene Palynology Laboratory in its study of Quaternary deposits in Canada. For more information on the other devices mentioned the reader is referred to standard texts on submarine geology and oceanography, comprehensive reviews such as Wright et al. (1965), or the numerous references quoted for specific devices. Discussion of equipment and techniques used in sampling buried deposits of unconsolidated sediments is beyond the scope of this paper and will not be attempted. Some suggestions for sampling available exposures of surficial deposits have been included to aid those interested in submitting samples for pollen analysis.

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SAMPLING TECHNIQUES

BOGS

Bog deposits, because of the fibrous nature of the material, do not yield good cores using tube-type coring devices. Even if the tube is thin-walled and the cutting edge is sharpened, it may still not be able to cut through fibrous or woody peat. If a plug of material is pushed ahead of the sampler a part of the sequence is not sampled. The most useful device for sampling peat, despite its antiquity (Fries and Hafsten, 1965), is still the Hiller peat borer (Pl. II).

The first requirement to sampling a bog is the determination of the location of the most complete sequence of sediments. This is generally in the deepest part of the bog. Bogs covering small areas are usually developed in a single basin, while larger bogs may cover several basins of various depths. Sampling for palynological purposes is best done in the smaller bogs. More detailed descriptions of bog development can be found in standard texts on palynology (Godwin, 1956; Faegri and Iversen, 1964). The deepest part of a small bog can be found easily by probing in a random fashion and moving in the direction of increasing depth. With larger bogs or where the stratigraphy of the bog is needed in more detail, probing can be done on a grid system and a depth contour map drawn. A Hiller peat borer can be used as a probe or a pointed steel tip attached to the extension rods can be used.

After determining the deepest part of the bog, cores are taken in 50 centimetre increments using the Hiller borer. If an aluminum liner is used in the core barrel the whole increment can be removed and kept as a sample. Otherwise smaller samples (about 2 cubic centimetres) are removed at 5 or 10 centimetre intervals, using forceps or a spatula, and placed in numbered plastic bags. The bog stratigraphy, as seen in the core should be described as accurately as possible in the field notebook, and the position of each sample indicated in the notes. Detailed notes taken in the field are essential for the later compilation of the stratigraphic sequence of sediments and accurate location of individual samples in the pollen diagram. The following example is one method used for the field description.

Core 2:	50 - 75 cm.	poorly decomposed, brown, fibrous Sphagnum peat.
	75 - 100 cm.	medium decomposed, dark brown, woody and fibrous Sphagnum peat.

Samples:	65 - 6 :	60 cm. from surface
	65 - 7 :	70 cm. from surface
	65 - 8 :	80 cm. from surface
	65 - 9 :	90 cm. from surface
	65 - 10 :	100 cm. from surface

The individual samples for each site are placed in a container bearing the identification number for that particular site. If the complete cores are kept the top should be marked and each core numbered successively and identified by a site number.

The sample chamber must be cleaned after each core is taken. A handy pool of water, wet moss from the bog surface, or a sponge and a pail of water are useful for this purpose.

It is preferable to use two adjacent holes for sampling and to alternate between the two to avoid sampling the material disturbed by the auger tip of the sampler while taking the previous increment.

The pollen record commonly begins in inorganic sediments beneath the organic deposits of the bog. It is, therefore, important to sample this material also. The Hiller borer generally is not suitable for this purpose, as silty and sandy sediments will bind the mechanism. A thin-walled tube sampler is better suited for sampling this material. Usefulness of the Hiller borer in obtaining samples for radiocarbon dating is somewhat limited. Because of the small bore diameter a horizon must be sampled a number of times to recover a sample large enough for dating. The tendency for this sampler to carry fibrous material down and incorporate it into lower samples makes radiocarbon dates on these samples unreliable.

To overcome these difficulties a large size sampler with a moveable piston, which utilizes a Shelby tube as a core barrel, was developed (Pl. III). The samples obtained are virtually undisturbed and free of contamination except for a thin skin of foreign material around the outside of the core, which can be easily removed with a knife or spatula. It may be necessary to open a hole with an auger or Hiller borer to the required depth for sampling as the large size of this sampler makes it difficult to penetrate fibrous or woody material. With the two hole method of sampling one hole is left with the contact between inorganic and organic sediments intact. The large piston sampler can be lowered into this hole to sample the desired interval. The core is extruded at the site, wrapped in aluminum foil, and labelled to show top and bottom, the site identification number, and the core number.

Where penetration of the basal inorganic sediments with either of the two devices mentioned above is difficult, a Davis sampler can be used. This device also works on the moveable piston principle, but is much smaller in diameter and length.

In addition to subsurface samples a sample of the growing layer (surface sample) of the bog should be obtained. This is best done by taking a handful of moss from the top 10 centimetres and using it as a sample, or by treating the fine organic matter in the water squeezed from the moss as the sample.

Besides the description of the sediments and the stratigraphic position of the samples the notes should include: 1) the exact geographic location of the site; 2) the altitude of the site; 3) its physiographic and geologic setting; 4) the size of the bog; and 5) its vegetation cover, and the vegetation of the surrounding area.

LAKES

The sampling of lakes poses numerous problems not encountered in the sampling of bogs; a means of moving about the surface of the lake, a stable sampling platform, and casing for sampling in deeper water are only a few of these problems.

Numerous methods and devices have been employed to sample lake bottom deposits, ranging all the way from oil drilling rigs mounted on ships (Zumberge, 1962) to simple pipes pushed into the sediment. Terasmae and Mirynech (1964) successfully used a truck-mounted soil-testing rig on the ice in winter to obtain Shelby tube samples of unconsolidated sediments from lakes. In oceanographic work where great depths of water are involved, various devices have been developed that employ a weighted tube that is driven into the sediment by its own weight. They commonly have some means of retaining the core, such as a core-catcher at the base of the tube and/or a check-valve at the top (Strom, 1934; Emery and Dietz, 1941; Hvorslev and Stetson, 1946; Phleger, 1951; Richards and Keller, 1961). This type of sampler is generally very heavy and requires a cable and powerful winch to retrieve it, although some attempts have been made to eliminate the cable (Moore, 1961). Smaller devices that work on the same principle have been developed for use in shallow water and lakes (Strom, 1937; Hanna, 1954; Callender, 1964), but like their larger counterparts they distort, disturb, or fail to recover some of the core (Emery and Dietz, 1941; Piggott, 1941).

Efforts to limit the amount of disturbance of the sediment have followed various paths. Taking the sample from alongside the core barrel after it has penetrated the sediment to the correct depth is one approach (Jenkin and Mortimer, 1938). Placing a piston inside the coring tube also improves the quality of the sample and increases the amount of core recovered. Large devices for oceanographic purposes have been developed using the stationary piston principle and good results have been obtained (Kullenberg, 1947; Heezen, 1952; Emery and Broussard, 1954). Cores of considerable length have been recovered from the ocean bottom in a single tube. Instead of trying to sample the complete sediment sequence in one tube, samplers have been developed that will penetrate a predetermined amount of the sediment before the piston is released and sediment can enter the tube (Kullenberg, 1955; Anderson et al., 1965). In this way the complete sequence is covered by several smaller increments.

A number of these heavy samplers have been redesigned for use in shallow water and some have been specifically designed for use in lakes (Silverman and Whaley, 1952; Ginsburg and Lloyd, 1956; Reish and Green, 1958; Wiechowski, 1961). Most of these samplers, despite their small size, still penetrate the sediment because of their weight alone. Others have been designed that are much lighter and are forced into the sediment by other means such as air pressure (Mackereth, 1958; Smith, 1959).

In the shallow water encountered in most small lakes, attaching extension rods to the sampler to drive it into the sediment becomes feasible. The type of device designed by Livingstone (1955) or modifications of it (Vallentyne, 1955; Rowley and Dahl, 1956; Cushing and Wright, 1965; Deevey, 1965) make the complete recovery of undisturbed samples routine. Even the previously difficult job of sampling an increment across the mud-water interface has become matter-of-fact with a sampler developed for this purpose (Brown, 1956).

Prior to sampling, water depths are determined using a Bendix depth recorder (Model DR-21), which gives a permanent record of the depths on paper. This unit is completely portable and is powered by standard flashlight cells or a 12-volt automobile battery. The transducer can be mounted on a suitable frame and suspended over the side of the boat. Depth profiles obtained by the recorder can be used to draw depth contours of the lake if a systematic survey of the lake is made. A flat-bottomed aluminum car-top boat 9 feet long and a 5 1/2 HP motor have proved useful for working on small lakes.

When the deepest part of the lake is found an indication of the type of bottom sediment is obtained using the gravity corer (Pl. VI). This device can be used for reconnaissance sampling of an entire lake bottom as it can be used effectively from an unanchored boat.

Sampling of the lake bottom is best accomplished from a raft that is as stable as possible. In the past a raft was made of two inflatable, two-man, rubber dinghies tied together side-by-side with a wooden platform placed over the top. The platform consisted of a plywood deck laid on a bolted, wooden frame. More recently, two flat-bottomed, aluminum car-top boats, 9 feet long and 4 feet wide have been used instead of the dinghies. The two boats are fastened side-by-side about 10 inches apart using three lengths of one inch square hollow steel rods bolted across the gunwales (Pl. I). Sampling procedures can then be carried out from both boats through the space between the two. The space functions as a hole in the centre of a raft and is more convenient than working over one side. This arrangement provides a stable sampling platform, which can be occupied by four men without too much crowding. The raft is anchored over the site by three or four heavy anchors (gallon pails of concrete are useful) arranged radially.

Casing, made from 3-inch aluminum alloy irrigation pipe, cut in 5-foot lengths, is used to prevent the extension rods from bending as the sampling device is pushed into the sediment (Pl. I). The casing is lowered to within a foot of the bottom and supported in this position by a frame on the raft. The sections are coupled together by means of sleeves made from thicker-walled (about 1/4 inch) aluminum pipe, large enough to allow the irrigation pipe to fit inside. A 6-inch sleeve is welded to one end of each length of pipe. The other end is locked in the coupling by means of two set screws. A special section, provided with a large diameter collar, which will not slip through the supporting frame, is always used as the top section. Another section, with a funnel at the lower end (Pl. I), is used as the lowermost section. This keeps the sampling devices from catching on the edge of the pipe as they are being pulled from the sediment into the casing. In shallow water the casing may not be needed, but in deep water it is indispensable.

When the casing is in place, the mud-water interface is sampled using the Brown sampler (Pl. IV), a stationary piston corer developed specifically for this purpose. A clear plastic core barrel permits examination of the core without extruding it and provides a convenient container for transporting the core to the laboratory. After a suitable core is obtained the tube is stoppered, taped, and properly labelled.

Before the Brown sampler with its core is pulled to the surface the position of the top of the casing is marked on the extension rods so that the second coring will begin at the depth reached by the first. The second core is generally obtained with a Livingstone corer (Pl. V). Unlike the Brown corer, this device can be forced into the sediment with the piston fixed at the bottom of the core barrel. When the sampler reaches the required depth the piston is released and a core, 1 metre long, is obtained. Sampling is continued, at one metre increments, until the sampler will advance no farther or until inorganic sediments unsuitable for pollen analysis are reached. Where radiocarbon dates are desired two or more cores are necessary to assure enough datable material. The cores are left in the tubes, which must be stoppered, taped, and properly labelled for transportation to the laboratory.

Where thickness of the sediment is great or the deposit is compact, some bending of the extension rods below the casing may occur. This can be partly overcome by adding more lengths and forcing the casing as far into the sediment as is possible while still being able to extract it afterwards.

Some lakes are too deep to be sampled effectively in the described manner, or are underlain by sediments that are too thick or too stiff to be sampled from a floating raft with hand-operated equipment. In such cases better results can be obtained by sampling through the ice during the winter season. The ice provides a stable platform, but the disadvantages of working in cold weather must be minimized by a little advance preparation.

Accurate descriptive notes similar to those outlined for bogs are also required for lakes. Cores should be clearly marked as to top and bottom, site identification number, and the stratigraphic interval covered. When the cores are extruded in the laboratory, a detailed description is made of the sediments in the same manner as indicated for the peat cores.

OTHER SURFICIAL DEPOSITS

Besides peat and lake sediments palynological studies commonly involve investigations of exposures of surficial deposits. Special sampling devices are not required but tools such as shovels, mattocks, and a sturdy knife to cut out small sample blocks are needed. Oxidation destroys pollen so the surface layer of the exposure must be removed to assure a fresh sample. This may create serious problems in very old exposures or in areas with dry climates, as considerable material may have to be removed before suitable samples can be obtained. Slumping is another problem that can be serious when sampling older exposures. Great care must be taken to obtain a fresh undisturbed face with which to work.

It is difficult or impossible to determine in the field which stratigraphic units contain pollen and hence, a complete sampling of all units is recommended. The sampling interval and sample size, however, need not be uniform throughout the exposed sequence. Thick sand and gravel units and glacial till commonly do not contain pollen. A few representative samples (top, middle, and bottom, or spaced several feet apart) are generally sufficient for such units. Thick beds of silt and silty clay or silty sand, which generally accumulate rapidly, can be sampled at 1-foot or 6-inch intervals. To allow such a thick unit to be completely represented channel samples (vertical, V-shaped cuts) extending in length from a few inches to a foot or more can be taken. Peat beds and organic lacustrine sediments should be sampled at 3- to 6-inch intervals, depending on the thickness of the unit.

A size of about one cubic inch is recommended for samples intended for palynological study. The size can be increased for sandy sediments and decreased for organic sediments. Scarcity of available material is not usually a problem when sampling exposures, as it is when using probing-type sampling devices, hence larger sized samples are taken.

Samples can be placed in small polyethylene bags. The sample number can be written on the outside of the bag using a brush pen. Labels should not be written on paper and placed inside the bag because if any moisture is present the label will deteriorate rapidly. The small bags can then be placed in a larger bag bearing the site identification number. Detailed notes describing the site and its location and a sketch showing the detailed stratigraphy and the sample locations are required to aid in compiling and interpreting the results.

The development of devices for sampling unconsolidated subsurface deposits on land has not progressed as rapidly as those for use in water, although in recent years several devices have appeared (van der Sluis and Schaafsma, 1963; Hageman, 1963). These have been mainly tubes that are forced into the sediment and differ only in their ways of limiting the disturbance of the sediment. An ingenious device using metal foil that moves up the inside of the core tube along with the core and prevents the moving core from coming in contact with the walls was developed in Sweden (Kjellman et al., 1950). This device yields undisturbed samples of great length, often in excess of 12 metres. Descriptions of these and other similar devices is beyond the scope of this paper and will not be attempted here.

SAMPLING DEVICES

PEAT SAMPLERS

Hiller Peat Borer

The Hiller borer (Pl. II) was described by Erdtman as early as 1935 and a description of it is included in most standard texts on pollen analysis (Erdtman, 1943; Faegri and Iversen, 1964). Prototypes of the Hiller were used before the turn of the century (Fries and Hafsten, 1965). A commercial model manufactured by Beus and Mattson, Mora, Sweden, is available in two sizes. One is of heavy construction and has a sample chamber diameter of 2.8 cm.; the other is much lighter and has a smaller diameter chamber. Both have sample chambers that are 50 cms. long. The chamber has a vertical slot that can be closed or opened by a clockwise or counterclockwise turn of the extension rods. As the sampler is pushed into the sediment the chamber is kept closed by a slight clockwise torque on the rods. When the desired sampling depth is reached a counterclockwise turn opens the slot and the protruding flange scoops the sediment into the sample chamber. A clockwise turn closes the chamber again before the sampler is pulled to the surface. The 1-metre long extension rods have a male-female type of joint, which is locked by a set screw. This enables the sampler to be rotated in either direction without disconnecting the sample rods. When removed from the hole, the outside of the borer is cleaned, the chamber is opened, and the core, or samples from it, are removed as described earlier. After thorough cleaning the sampler is ready for sampling the next increment.

Several disadvantages of the Hiller sampler are: 1) it is very difficult to keep some contaminating materials from entering the chamber while the sampler is being pushed into the sediment; 2) the sampler cannot be used in compact sediment because it must displace the sediment before the sample can be taken; 3) coarse-grained sediments can jam the mechanism making sampling impossible; and 4) samples are always disturbed and physical and structural properties are changed. Although the Hiller sampler has a number of disadvantages it is still the best device available for sampling peat or other fibrous or woody sediment. Also, it is compact, easy to use, and is useful for reconnaissance work where contamination is not a serious factor.

PISTON CORERS

Two basic types of piston corers have been developed. In one type a loose-fitting piston, connected directly to the extension rods, is lifted to the top of the sampling tube before the sample is taken. In the other the piston is not connected to the extension rods, but is controlled by an attached cable or small rods within the extension rods. At the required sampling depth the piston is held stationary and the tube is pushed past it into the sediment. The purpose of a moveable piston is to prevent sediment from entering the core tube before the correct sampling depth is reached. The piston must be loose fitting as otherwise the force required to raise the piston to sampling position would also lift the core tube. A tight fitting stationary piston not only prevents unwanted sediment from entering but also improves the quality of the core. The negative pressure created below the piston as the tube is pushed into the sediment draws the core up the tube and helps prevent compression and distortion.

Moveable Piston Corers

GSC Piston Corer

Two different sized devices are available. The larger sampler uses a standard Shelby tube (2 inches I.D. – 28 inches long) as the actual sampling tube; the smaller device is shorter and is made of a smaller diameter steel tube (Pl. III).

Both samplers work on the same principle as the Dacknowsky sampler (Faegri and Iversen, 1964). The piston prevents the sediment from entering as the tube is pushed into place. When the desired depth is reached the piston is moved to the top of the tube by lifting up on the rods. Splines along the interior shaft connected to the piston pass through matched slots in the collar of the sampling tube. Giving the rods a quarter turn orients the splines at right angles to the slots, seating them on the collar of the sampling tube and the tube can then be pushed into the sediment to obtain the required sample. After lifting the sampler to the surface the core can be extruded by pushing the piston to its original position at the bottom of the tube. The sampler is ready to use again after a thorough washing to remove all sediment clinging to the tube.

The 3-foot long extension rods of one-half-inch steel water pipe are joined by threaded couplings. This means that turning the sampler in a counterclockwise direction during the sampling procedure might uncouple the rods. Pipe wrenches or pressure lock pliers are needed to couple and uncouple the rods. The size of the sampler and the type of rods used make this equipment very heavy. This device cannot be used to sample in water because it is the friction of the sediment that keeps the sample tube from falling to its extended position prematurely.

The size of core obtained and the rugged construction of these samplers makes them very useful. They are simple to operate and inexpensive to make and to repair.

Davis Sampler

Another sampler incorporating the moveable piston principle is the Davis sampler (Bastin and Davis, 1909). Most models have a tube 15 inches long with an inside diameter of 1/2 inch. The sampler is driven into the sediment with the piston at the lower end closing the tube. At the required depth the rods are lifted until a spring loaded catch is released, securing the rods to the upper collar of the tube. The open tube is then pushed into the sediment and the sample fills the tube. On surface the spring catch is released and the sample extruded. The device obtains a core about 10 inches long.

The small sample size limits the use of this sampler. However, it is valuable as a probing tool and for sampling stiff, compact sediment that cannot be sampled with larger devices.

Stationary Piston Corers

Brown Sampler

The Brown sampler (Pl. IV) was developed to overcome the problems of sampling the mud-water interface of lakes. This is generally very difficult to sample because of the loose nature of the sediment. The original details of construction as described by Brown (1956) have changed little, with only a few minor refinements being made to the piston and head piece.

The piston consists of a rubber stopper, with the bevelled sides ground parallel, sandwiched between two aluminum discs. A threaded rod passes through the centre of these with a wing nut on either end of the rod holding the assembly in place and allowing the stopper to be compressed or released. The diameter of the stopper can be adjusted using the wing nuts until the piston fits snugly in one end of the plastic sampling tube. The piston must fit tightly enough to hold water, but be loose enough to move easily up the tube. A wire, attached to the piston by a coupling, extends the length of the tube and through the head piece. One-sixteenth inch, galvanized aircraft cable is used for this purpose. This cable is attached to another leading to the surface.

A head piece made of two rubber stoppers, with the bevelled edges removed, on a central threaded rod fits loosely into the upper end of the plastic tube. Aluminum discs are placed on either side of each stopper. Three spacer rods fitted between and set in the inner discs hold the stoppers 4 inches apart. Holes through the discs and stoppers allow the wire connected to the piston to pass through and also permit water to pass the head piece freely. A wing nut on the lower end of the rod and a knurled flange on the upper end allow the stoppers to be compressed to fit tightly in the tube. If the upper disc is the same diameter as the outside of the plastic tube the disc will seat on the rim of the tube and prevent the head piece from being pushed into the tube. The tightened stoppers will keep the head from pulling out of the tube. The top of the centre rod is fitted with an adapter for attachment of the extension rods. Lichtwardt-type extension rods (Pl. VII) are used with this sampler.

The plastic sampling tubes are 4 to 6 feet in length, with an inside diameter of 2 inches. Cast tubes have proved to be much longer lasting than the extruded type and are much smoother inside so that the piston moves more easily. They are, however, more expensive.

To operate the sampler, after it has been assembled, the tube is filled with water and the piston placed in position at the lower end. Care must be taken when lifting the filled sampler out of the water to see that no water escapes and that the wire is clamped to hold the piston in place. In shallow water where casing is not used the sampler does not have to be lifted from the water after it has been filled. Extension rods are attached and as the sampler is lowered to the required depth the wire is played out and kept taut enough to take up any slack without pulling the piston up the tube. When the sampler is just above the mud-water interface the wire is clamped at the surface so the piston is held in place and the tube is pushed into the sediment. Sampling is complete when the piston comes in contact with the head piece. The sampler is then raised to the surface and a rubber stopper placed in the lower end.

After removal from the water, the head piece is removed by loosening the knurled flange, the water above the piston is decanted, and the piston pulled out. Removal of the piston may be difficult because of the vacuum created below it. Pulling against this vacuum may disturb the loose sediment in contact with the water, but this disturbance can be minimized by pulling as gently as possible until some air passes the piston. The piston is usually easily removed after this happens.

To transport the sample to the laboratory the tube is refilled with water (except for a small airspace to allow for expansion), a rubber stopper is placed in the upper end, and both stoppers are taped tightly to hold them in place. An elastic vinyl tape (Scotch No. 33, electrical insulating tape, width 3/4 inch) has proven most useful for this purpose. The tube can then be moved in an upright or inclined position. Laying the tube flat will cause mixing of the upper soft sediment.

In the laboratory the water is siphoned off. The very loose sediment can be siphoned off or it can be extruded along with the rest of the core. If the core is extruded in the horizontal position some mixing of the loose sediment may result. If extruded in the vertical position a small collar with a pouring lip can be attached and the loose sediment collected in increments as it pours over the top of the tube. The stiffer sediment can be removed by slicing off increments as the sediment is exposed above the tube. Freezing the core before extrusion is one method that has been used (Wright et al., 1965), but this may change the physical properties of the sediment somewhat.

By using a plastic tube the core can be examined when it is taken and if it is not suitable it can be discarded and another taken. This device was designed to sample the mud-water interface and cannot be used below this first sampling interval. The piston is held in the bottom of the tube by friction alone and if it is pushed into the sediment in this position it will be forced up the tube before the proper sampling depth is reached. Despite its limitations this sampler is the best and most efficient device for taking undisturbed cores of very loose sediment at the mud-water interface. A plastic tube longer than 6 feet could be used to obtain longer cores, but no tests have been attempted on such an innovation to date.

Livingstone Sampler

After obtaining a core of the loose sediment at the mud-water interface and some of the more compact sediment immediately below it with the Brown sampler, the Livingstone sampler (Pl. V) is used for further sampling. Unlike the Brown, the piston of the Livingstone sampler is held in position at the lower end of the coring tube by two retractable pins, thus allowing the tube to be pushed into the sediment without forcing the piston up the tube.

In the original design by Livingstone (1955) the piston had spring-pins and leather washers. The sampler purchased by the Geological Survey of Canada from the Gibbs Laboratory, Yale University, New Haven, Connecticut, incorporates the modifications outlined in detail by Deevey (1965). The piston is made entirely of brass and will fit inside the coring tube. A rubber stopper at the top of the main housing of the piston can be compressed by a nut so that it will fit snugly in the tube. A conical tip on the lower end of the housing makes sediment penetration easier. A central shaft, with one end exposed above the top of the housing where the cable can be attached, is connected at its lower end to the retractable pins inside the housing. The mechanism is such that when the central shaft is pushed into the piston the pins project and prevent the piston from riding up the tube. When the shaft is pulled upward, which happens when the cable is clamped and the sampler pushed down, the pins retract and the open tube can move past the piston into the sediment.

The cable attached to the central shaft of the piston passes through the sampling tube and out the head piece where it is joined to another cable leading to the surface. The head piece fits into the upper end of the tube and is held in place by a pin. Lichtwardt-type extension rods are connected to the head piece. The aluminum alloy core tubes are 1 1/2 inches inside diameter and are long enough to yield 1 metre of core. (See Deevey, 1965, for complete details of materials and construction.)

Vallentyne (1955) used modifications to the extension rod assembly to prevent the piston from being pushed up the tube by the sediment. A second rod was made to pass down the centre of the extension rods and connect to the piston, thereby controlling it more effectively. Rowley and Dahl (1956) incorporated two rubber stoppers into the piston to replace the leather washers. Other modifications have been described by Cushing and Wright (1965).

To obtain a sample the assembled instrument is pushed into the sediment to the required depth using the attached extension rods. The cable is played out with the rods, but held taut enough to remove the slack without causing the pins to retract. Upon reaching the required depth the cable is clamped to hold the piston stationary. A push on the rods causes the pins to retract and the sampling tube is pushed into the sediment a distance of one metre. If the sampler cannot be driven one full metre into the sediment, for some reason other than hitting a hard bottom, the core should be discarded and the increment repeated. Unless the reason for obtaining the shorter core is known it must be assumed that the piston was released prematurely and sediment allowed to enter before the proper sampling depth was reached.

After the sampler is hauled to the surface, a rubber stopper is placed in the lower end, the head piece removed, and the water above the piston poured off. The piston is then removed by pulling on the cable; the top end is also stoppered, and both stoppers taped in place. As the core does not completely fill the tube it is best to transport the tube in a slightly inclined position to limit the disturbance. The sampler is then reassembled using another tube and the procedure is repeated.

Several years use have proven this sampler to be one of the best for sampling lake deposits. It is light-weight, simple to operate, and provides excellent undisturbed samples from organic and soft fine-grained mineral sediments. Coarse silt- and sand-sized particles within finer grained sediments tend to jam the piston. Coarse silts and sands and compact, stiff sediments cannot be penetrated with this sampler.

GRAVITY CORERS

GSC Gravity Corer

The gravity or free-fall corer (Pl. VI) is essentially a weighted tube that penetrates the lake bottom sediments by the force of its own weight. The amount of penetration is dependent upon the weight of the device, the distance of fall, the character of the sediment, and the dimensions of the sampling tubes. An attached cable is used to retrieve the sampler after penetration.

The upper end of the core tube is equipped with a valve that permits water to escape as the sediment enters the tube, but holds the core in the tube by suction as the tube is pulled out of the sediment and to the surface. The opening in the valve must be large enough to allow the water in the tube to escape as quickly as the tube penetrates the sediment, otherwise pressure builds up and the sediment is pushed aside. This results in an incomplete or short core. The type of valve found to work best thus far consists of a hard rubber lacrosse ball that is free to move about within the cage-like head. As the sampler drops through the water the ball moves away from the hole at the top of the tube and allows free passage of the water. When the sampler stops the ball drops to the bottom of the cage and becomes seated in the bevel-edged hole thereby blocking it.

The plastic coring tubes are 1 1/4 inches inside diameter and either 2 or 4 feet long. They fit loosely inside an aluminum tube, which shields the weaker plastic. A stainless steel coring head screws onto the lower end of the aluminum tube and holds the plastic tube in place. On the upper end the valve assembly is attached to the aluminum tube by a threaded joint. When the two ends are tightened the plastic tube is seated at each end on rubber washers that make the whole assembly watertight. The inside diameter of the coring head is slightly less than that of the plastic tube. The core entering the plastic tube is smaller than the tube diameter, thereby reducing the friction and allowing the core to move up the tube more freely. The smaller diameter coring head also helps to hold the core in the tube. A rod with three fins and an eye to connect the retrieving cable is attached to the valve assembly. The fins help to keep the sampler upright as it falls through the water. Lead weights can be added to the rod to increase the total weight of the sampler and improve penetration.

Although this type of sampler, or similar devices with pistons, are widely used in oceanographic work where other means of sampling are not feasible, it has very limited use in palynological sampling. As the original hole made by the first drive cannot be located a second drive to obtain samples of the sediments beneath cannot be made. If weights are added and the length of the sampling tube is increased in an effort to obtain longer and more complete samples the instrument becomes more difficult to handle. The heavier sampler requires a winch, thereby increasing the costs considerably. A small sized device of this type is useful for reconnaissance sampling in larger lakes or in deep water, but for most purposes in small lakes other types of samplers are more useful.

MISCELLANEOUS DEVICES

In some instances augers, such as the ship's auger (Pl. VII), have been used to advantage. Although contamination is a major factor samples taken with an auger can be used for pollen analysis if care is taken. When stiff mineral sediments are encountered below organic deposits or where such sediments cover organic materials the auger is often the only means of penetration. In stony or pebbly materials removal of the small screw tip often helps penetration. Even a small stone will stop this point but with the tip removed the broader fluted end can often pass small stones along with the sediment. The type of extension rods used with the augers depends on what is being sampled. The auger in Plate VII is adapted for use with Lichtwardt rods. For very tough work rods made of steel water pipe are more rugged and much stronger. If screw type connections are used care must be taken not to undo the connection by turning the auger the wrong way.

Permafrost has always been very difficult to sample and various methods have been used to sample it successfully. The Courtemanche permafrost borer (Potzger, 1955) is a simple device, consisting of a tube with two cutting teeth, that has proved successful for this purpose.

Day et al. (1961) modified this basic design somewhat and added more cutting teeth. A hand operated Sipre ice-corer (manufactured by Ab Stålsvets, Sollentuna, Sweden) has been used to core permafrost, and a motorized version (Hughes and Terasmae, 1963) has also proved to be very effective. Opening a hole with a water jet and sampling at increments with a small tube as the hole is deepened is another method that has been used (Gerard, 1954).

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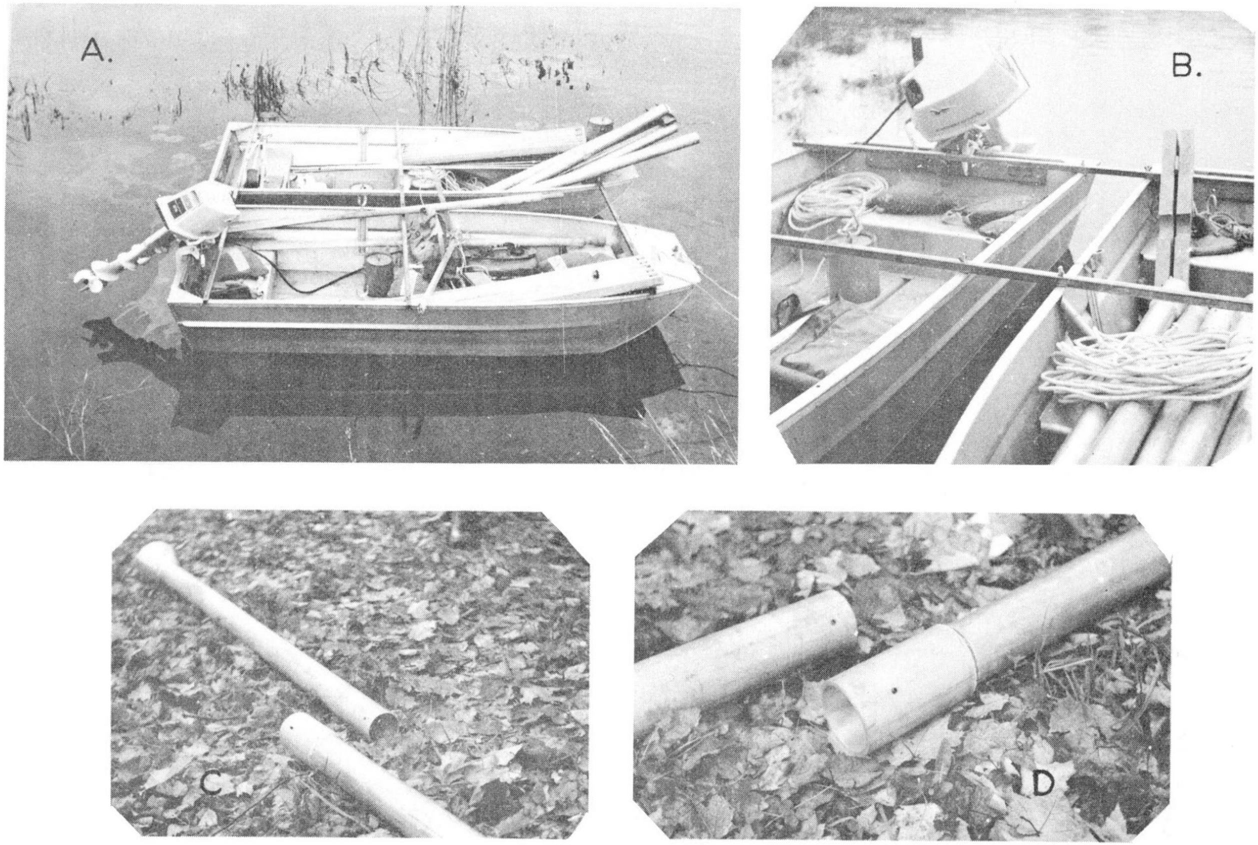

Plate I. A. Assembled raft. B. Steel rods bolted across gunwales to stabilize raft. C. Casing. Funnel end prevents equipment from catching on end of casing. D. Coupling.

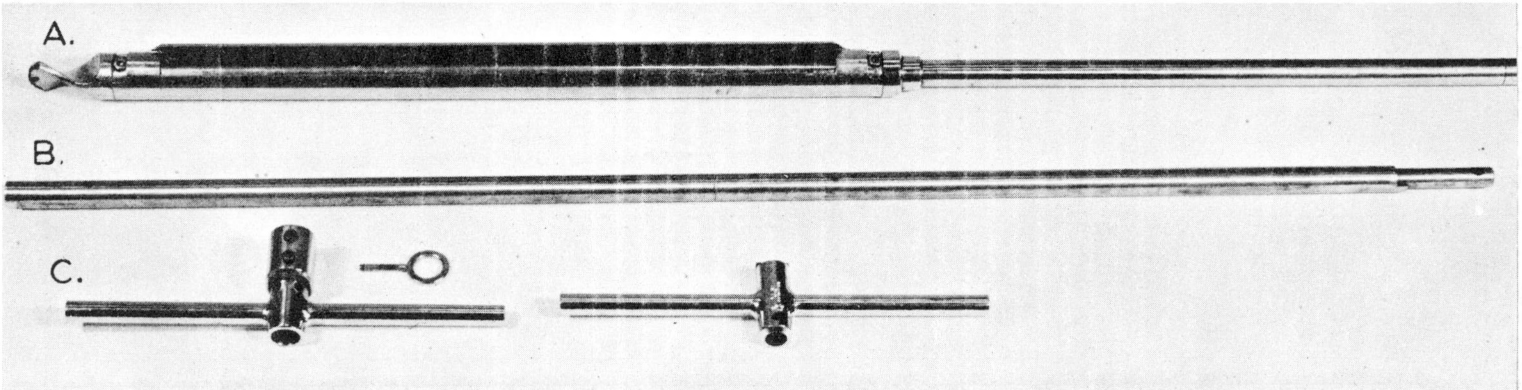

Plate II. Hiller peat borer. A. Sample chamber (50 cms. long). B. Extension rod. C. Handles and allen screw key.

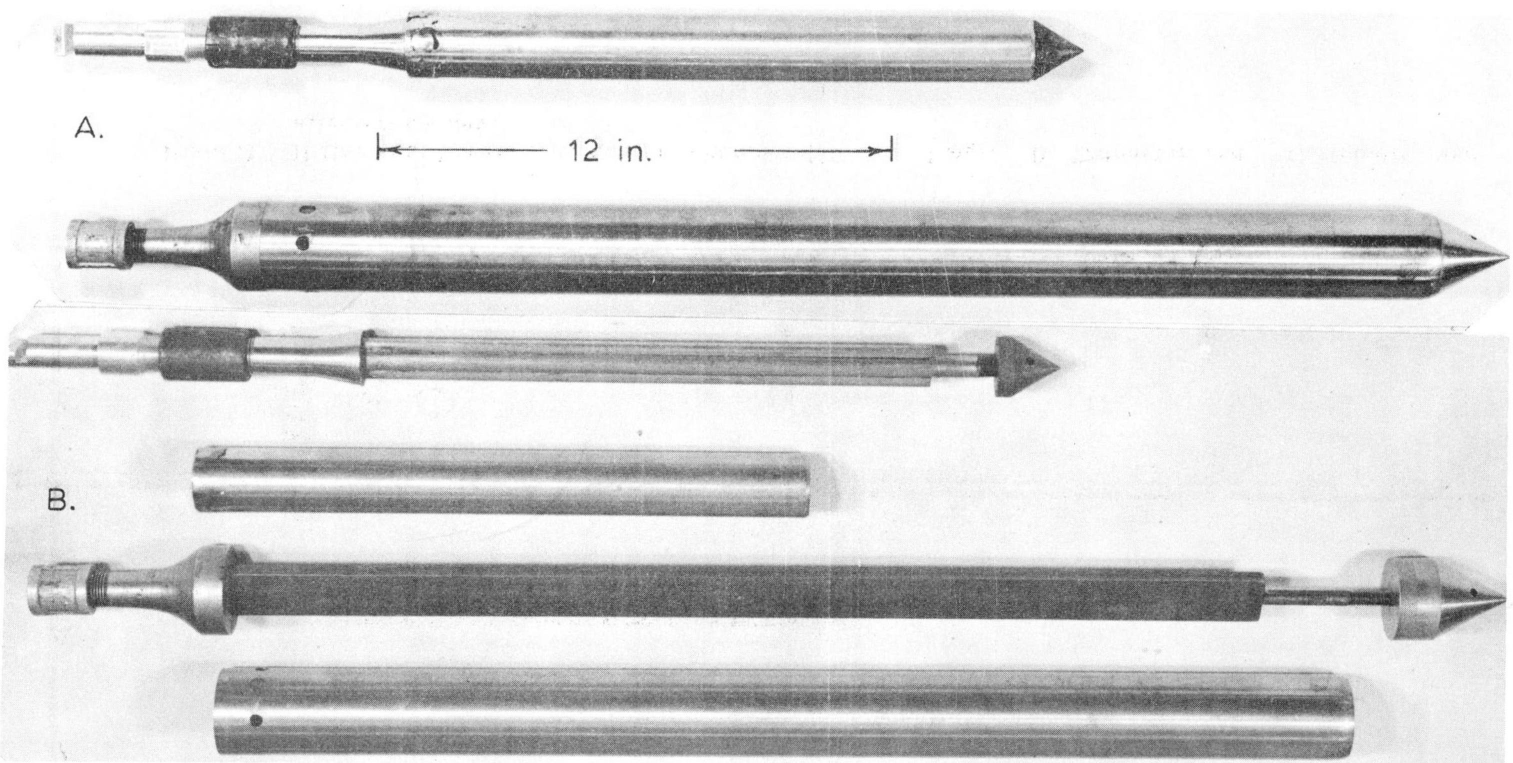

Plate III. G.S.C. piston corers. A. Small and large corers assembled for use. B. Core tubes removed to show central shaft and splines.

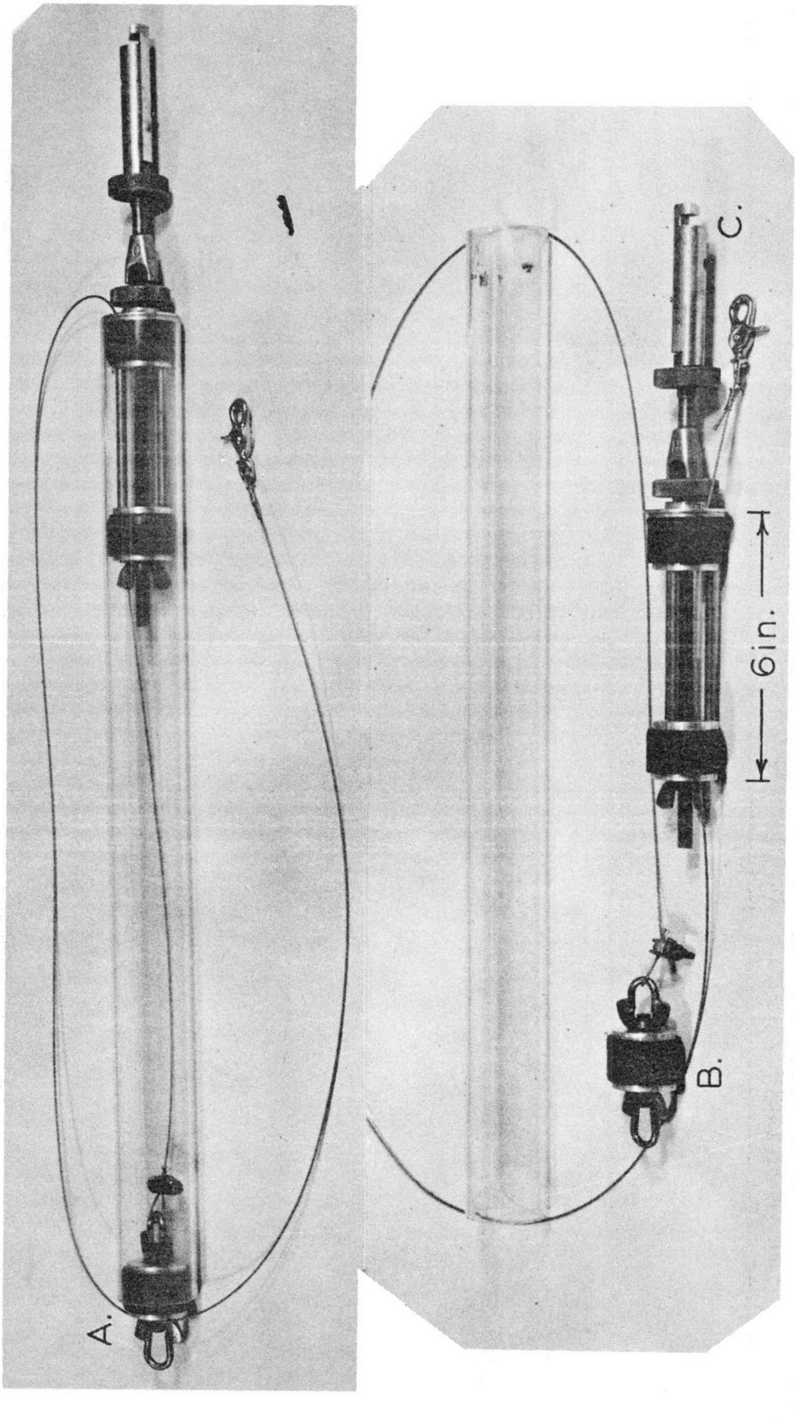

Plate IV. Brown sampler. A. Assembled sampler. B. Piston. C. Headpiece.

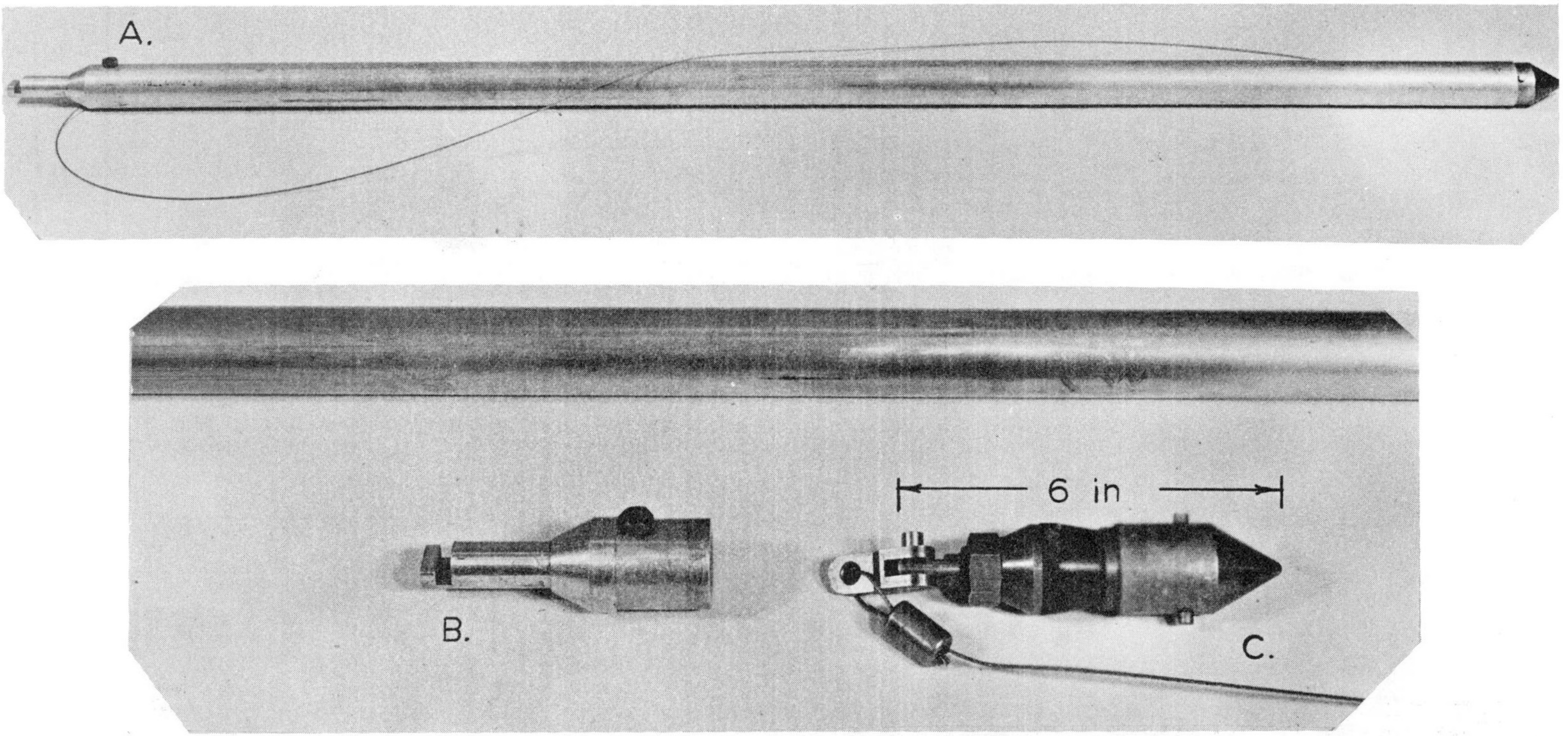

Plate V. Livingstone sampler. A. Assembled sampler. B. Headpiece. C. Piston.

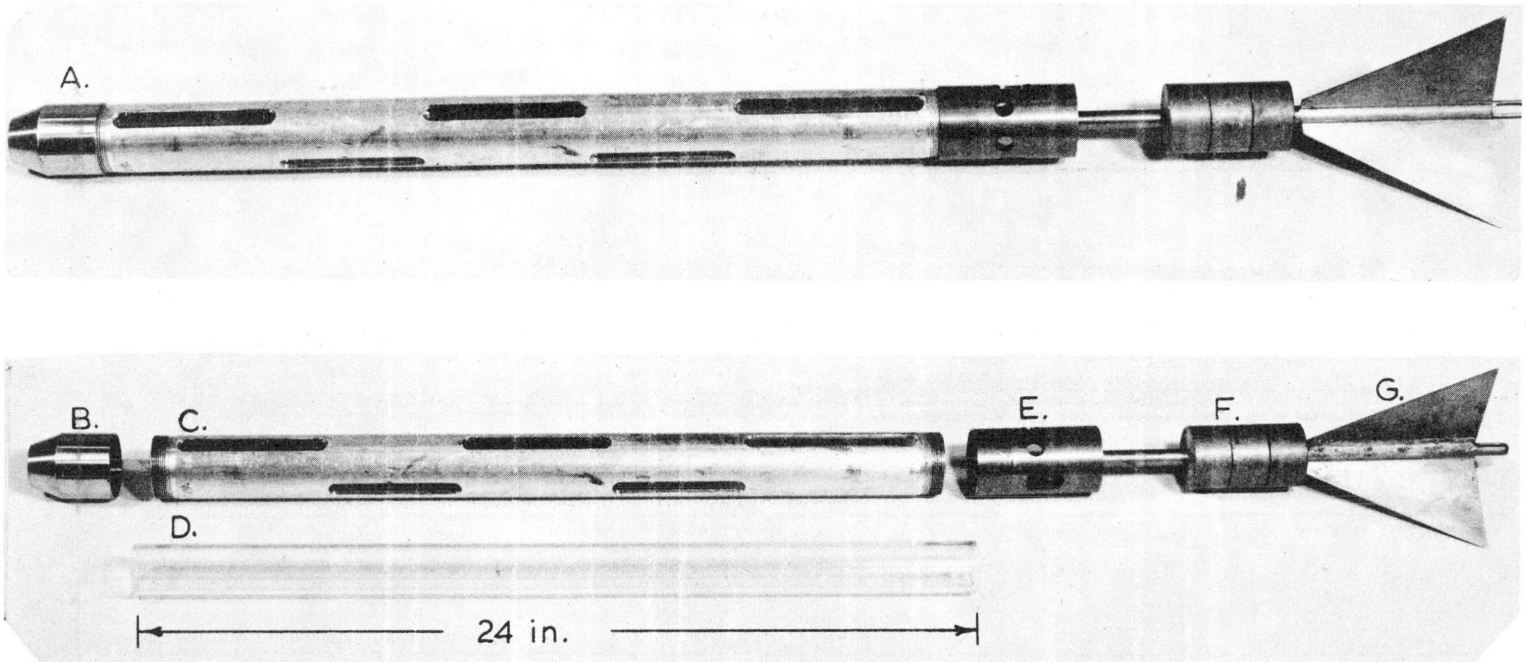

Plate VI. G.S.C. gravity corer. A. Assembled corer. B. Coring head. C. Aluminum shield tube. D. Plastic core tube. E. Valve assembly. F. Lead weights. G. Fins.

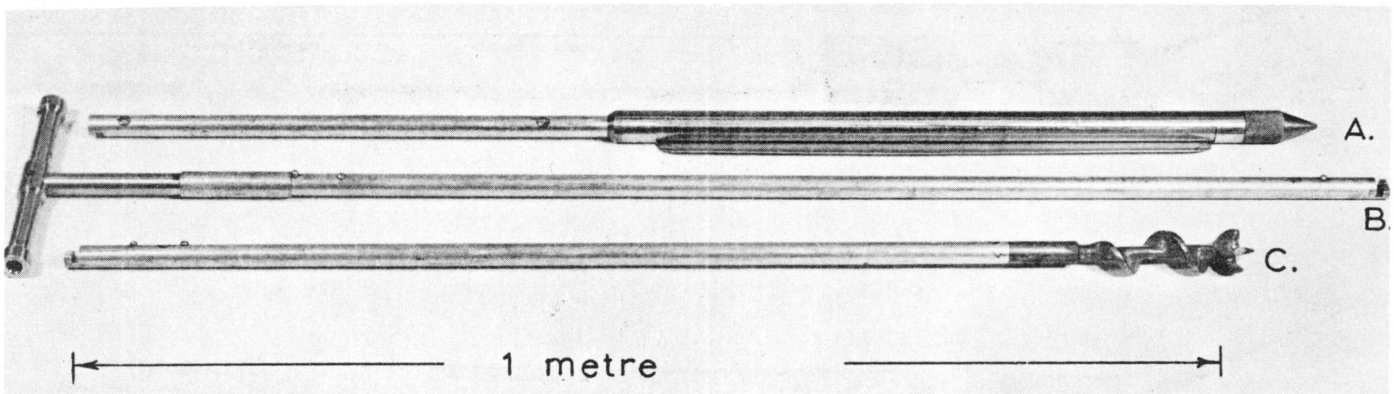

Plate VIII. A. Modified Hiller sampler with wide flange. For use with Lichtwardt rods.
B. Lichtwardt extension rod and handle.
C. Auger for use with Lichtwardt rods.