Manufacturer	*Apparatus*
Kelvin and Hughes (Marine) Ltd. St. Clare House, Minoroes London, E.C. 3, England	van Veen Grab
Laboratoire Océanographique P. O. Box 19 Charlottenlund Slot Charlottenlund, Denmark	Petersen Grab van Veen Grab Knudsen Suction Corer
Marine Instruments Ltd. 107 Fenchurch Street London E.C. 3, England	Knudsen Suction Corer
C. M. Murray Instrument Co. 7715—5th Avenue South Seattle, Washington	Clamshell Snapper Grab (Ross Type)
Richter and Wiese Kreuzbergstrasse Berlin S.W. 61, Berlin	Birge–Ekman Grab
Rigosha Mfg. Co., Ltd. 2 Kajicho 1–Chome Kanda, Chiyoda-Ku Tokyo, Japan	Seki Type Grab Birge–Ekman Grab Ekman–Lenz Grab Clamshell Snapper Grab (Ross Type) Marukawa Grab Kitahara Corer Gravity Corer with Sigsbee weight release Okamoto Gravity Corer Kullenberg Corer Niino Impact Corer Naumann Impact Corer "Scoopfish" Underway Sampler Rock Dredges Cup Lead
Tsurumi-Seiki Kosakusho Co., Ltd. 1506 Tsurumi-Cho, Tsurumi-Ku Yokohama, Japan	Clamshell Snapper Grab (Ross Type) Marukawa Grab Gravity Corer (short) Kullenberg Corer Rock Dredges Cup Lead
Wilks Precision Instruments Co., Inc. 4821 Bethesda Avenue Washington 14, D.C.	Gravity Corers Piston Corers

The Hunt Sampler may be borrowed from or copied at the Plymouth Laboratory.
The Ekman Bottom Grab will be built by the physical institute workshop of the University, Uppsala, Sweden.
The Enequist Sampler may be borrowed from Klubban's Biologiska Station, Fiskebackskil, Sweden.
The Hjort–Ruud Sampler will be built at the Biological Laboratory of the University, Frederiksgate 3, Oslo, Norway.

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A SURVEY OF MARINE BOTTOM SAMPLERS

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CONTENTS

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INTRODUCTION

Marine bottom samplers are designed for specific tasks and no one sampler is adequate for all purposes. A wide variety of devices have been invented for both biological and geological research to scrape, suck or core samples from the bottom. Though there is much diversity in the design and function of marine bottom samplers, certain specifications should be met by any sampler if it is to be practically and successfully operated from a vessel. These specifications are: (1) the device should have a minimum number of working parts and these should be corrosion-resistant, (2) the sampler should be sturdy enough to endure repeated handling on deck and impacts on the bottom, (3) the bulk or weight should be such that the sampler is not overly dangerous to handle on deck, (4) the sampler should orient correctly before contacting the bottom, (5) sufficient weight or power should be supplied to ensure penetration to the desired depth, (6) retrieving should entail no sample loss and once on board the sample must be relatively easy to remove.

This paper brings together the descriptions of a wide variety of bottom samplers which have been designed both for biological and geological work. Many of these devices no longer see service, but their descriptions are included both for historical interest and as a source of ideas for new equipment. The categories chosen for samplers in this paper are arbitrary and a considerable number of the samplers described can readily fit in several categories (e.g., many samplers classed as piston corers are also gravity corers and numerous samplers classified as manual corers are piston corers as well). The discussion of each device contains a brief account of its essential features, often an evaluation of its performance, and in most cases a line drawing. Bottom dredges (i.e., frames to which some sort of bag is attached) used primarily for biological work will not be treated. A guide to the literature on biological dredges can be found in a recent article by GUNTER (1957).

* Florida State University Oceanographic Institute No. 199.

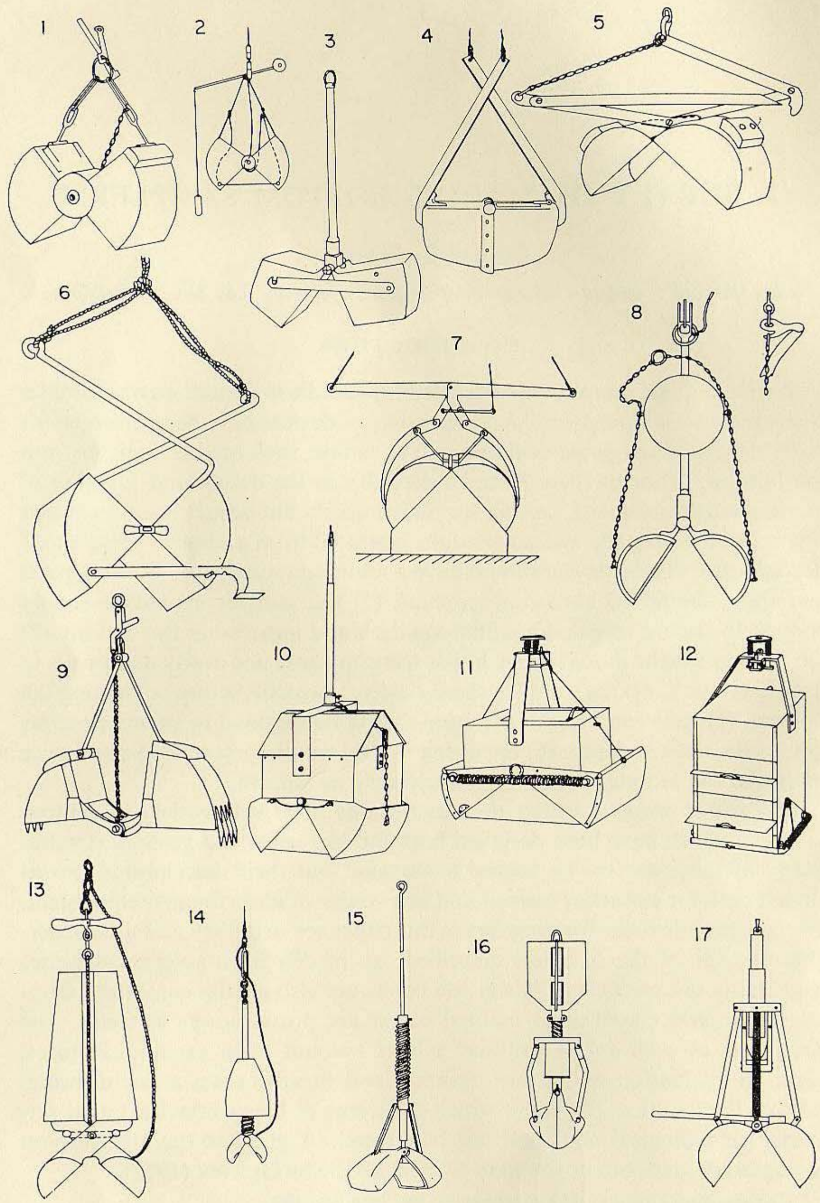

FIG.
1 Petersen grab—Petersen, 1911
2 Lisitzin–Udintzev grab—Lisitzin and Udintzev, 1955
3 Leger grab—Leger, 1904
4 Van Veen grab—Thorson, 1957
5 Foerst "Petersen" grab—Foerst catalog
6 Bottom snapper grab—G. M. Mfg. Co. Bull. A.
7 Klassen grab—Borutsky, 1952
8 Ulsky grab—Snerzhinskii, 1951
9 Seki bottom grab—Rigosha Mfg. Co. Cat. 180
10 Ekman grab—Ekman, 1911
11 Birge–Ekman grab—Rigosha Mfg. Co. Cat. 180
12 Ekman–Lenze grab—Rigosha Mfg. Co. Cat. 180
13 "Bulldog" grab—Thoulet, 1890
14 Ross clamshell grab—Snerzhinskii, 1951
15 "Fish hawk" clamshell grab—Hough, 1939
16 LaFond–Dietz grab—G. M. Mfg. Co. Bull. A.
17 Franklin–Anderson grab—Franklin and Anderson, 1961

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GRAB TYPE SAMPLERS

(Devices with jaws which are forced shut by weights, lever arms, springs, or cords)

Petersen Grab. The widely used Petersen grab (PETERSEN, 1911) consists of two weighted jaws which are held open by one of several types of catch mechanisms. When the sampler strikes the bottom the shock releases the catch so that the jaws are free to close. The sampler (Fig. 1) bites $1/10\ m^2$ out of the bottom surface, the jaws biting deeper the heavier the grab and the softer the sediment. The $1/5\ m^2$ model is used in deep water and although it is unhandy for small craft, it is well fitted for larger, more stable vessels (THORSON, 1957). It has functioned successfully at depths exceeding 10,000 m. The Friedling modification of the Petersen grab (NAUMANN, 1925) is closed by cords which cross from one jaw to the other. A version of the Friedling grab which is especially effective in deep water is that of Lisitzin and Udintzev (LISITZIN and UDINTZEV, 1955). This sampler has a suspended weight which strikes the bottom first and allows free fall for a short distance. Free fall is advantageous since certain tripping mechanisms tend to "lock" because of lowering tension. This model (Fig. 2) is widely used in the U.S.S.R. (L. A. ZENKEVITCH, Inst. Oceanol., U.S.S.R. Acad. Sci., personal communication) and has shown excellent operational qualities.

Leger Bottom Grab (LEGER, 1904). The Leger grab resembles the Petersen model except for the shape of the jaws and the release mechanism (Fig. 3). It consists of two jaws which hinge at the bottom of a rod and are held apart by iron straps. When the sampler strikes the bottom, one side of each strap is disengaged and both jaws are free to close. If a large particle prevents the sampler from closing completely, the jaws are so constructed that much of the sample will remain in spite of washing during hoisting.

Van Veen Grab—$1/10\ m^2$ (THORSON, 1957). The van Veen sampler (Fig. 4) has the same jaw construction as the Petersen grab. Each jaw, however, is levered shut with the long bars. It collects three times as much material on hard sandy bottoms as the Petersen grab (THAMDRUP, 1938), but the levers are awkward and waves or swells at the surface will often close the grab prematurely. It is successful on hard level bottoms down to several hundred meters and is considered a good supplement for the Petersen sampler. A heavier $1/5\ m^2$ van Veen is also in use (THORSON, 1957).

Foerst "Petersen" Grab (Foerst catalog). The popular Foerst sampler (Fig. 5) combines features of both the van Veen and the Petersen grabs in that it has the weighted jaws of the Petersen and the lever arms of the van Veen. The tripping mechanism consists of a bar holding the levers apart above the jaws. The tripping bar occasionally fails to fall free from the levers, particularly on hard bottoms (personal observations).

Emery Grab (KORNIKER, 1958). The Emery modification of the van Veen (Fig. 6) is lowered with the jaws open and the tripper extended downward. When the tripper hits the bottom, it is forced upward, thus freeing the jaws. It has a capacity of 2 liters.

Klassen Grab (BORUTSKY, 1952). This $0.09\ m^2$ sampler (Fig. 7) has jaws in the form of half cylinders which are freed on contact with the bottom by a release mechanism operated with a separate rope. The jaws are forced shut by levers. BORUTSKY (1952) states that this is the first quantitative bottom grab, but this claim is contested by THORSON (1957).

Ulsky Grab (SNERZHINSKII, 1951). The 25 kg Ulsky device (Fig. 8) has two large brass cups weighted with cast iron strips. These cups pivot on the lower end of a rod. When the grab strikes the bottom, the extended cups are forced into the sediment by their own weight and by a mobile load which when released, slides down the rod and impacts near the top of the cups. This grab has returned samples from depths of 1000 m without sample washing.

Seki Grab (Rigosha Mfg. Co. Catalog 180). The Seki apparatus (Fig. 9) is a $500\ cm^3$ sample capacity grab designed for shallow water research. The weighted jaws which are equipped with interlocking teeth are held in the open position by rods supported by a catch mechanism above the sampler.

Ekman Grabs. The Ekman grab is a widely used sampler originally designed for fresh water, but which has since been modified for marine work. In its original form (EKMAN, 1911), it is a box-shaped sampler with two scoop-like jaws (Fig. 10). The jaws are held in the open position by chains which are connected to pins on the closing mechanism above the sampler. On striking the bottom, the rod, to which the lowering line is attached, continues its downward progress inside a guide of larger diameter and carries the closing plate away from beneath the two pins. The chains then slip off the pins and allow the jaws to close. The Ekman sampler operates best in soft sediments and obtains samples with undisturbed stratification. Access to the sample is gained by a trap door on the top of the container. A heavier model (EKMAN, 1933) for marine work, with essentially the same closing mechanism, has flanges on the side to control the depth of penetration and sliding weighted panels resting on the scoops to force them shut when the chains are released. The Birge–Ekman Grab (BIRGE, 1922; G. M. Mfg. Co. Bulletin A) is a messenger operated modification of the Ekman sampler and its jaws are closed by much more powerful springs (Fig. 11). The jaws are designed to overlap in order to prevent washing. The Ekman–Lenz Grab (LENZ, 1931), also messenger operated, has a removable panel on one side which allows shelves to be inserted for the partitioning of the sample. Since the first appearance of the Ekman–Lenz Grab (Fig. 12) much stronger closing springs have been substituted on the jaws (Rigosha Mfg. Co. Cat. 180).

"Bulldog" Grab (THOMSON, 1874). This sampler, which was used aboard the vessel *Bulldog* in 1860, is the forerunner of the modern clamshell snapper grabs. It consists of a pair of scoops that are closed by a heavy rubber band. During descent a weight holds the jaws apart. When the sampler strikes the bottom, the weight falls off and the cups close. The Ross "Clamshell" or "Telegraph" Grab (HOUGH, 1939; SNERZHINSKII, 1951) is similar to the "Bulldog" device in that two small cups are hinged on the lower end of a shaft (Fig. 14). A catch mechanism located within the cups is released when the device hits the bottom and a strong coiled spring, mounted on the shaft, serves to force the cups shut. Occasionally impact on soft sediments may not be sufficient to trip the catch. The "Fish-Hawk" model (HOUGH, 1937) of the Ross sampler has the catch located on the shaft above the spring instead of within the cups (Fig. 15).

LaFond–Dietz Grab (LAFOND and DIETZ, 1948). The LaFond–Dietz sampler is a heavy foot-triggered grab which has its jaws closed by powerful spring action (Fig. 16). The spring, mounted on the central shaft above, acts on arms to close the jaws. This 27 kg sampler functions well on all types of bottom—even rock—and takes a 470 cm^3 sample (G. M. Mfg. Co. Bulletin A).

Franklin–Anderson Grab (FRANKLIN and ANDERSON, 1961). The Franklin–Anderson grab is a spring-loaded sampler with a powerful closing action (Fig. 17). The half cylinder jaws are cocked open by levers which force arms, extending to the outside of the scoops, up the central supporting shaft until toggles are engaged in slots in the shaft. The jaws are released when the sampler strikes the bottom by a free falling weight which slips down the shaft to disengage the toggles. The springs, which run between the hinge line of the jaws and the top of the arms, are then free to pull on the arms. The arms in

turn put pressure on the outside of the scoops. This 2500 cm^3 capacity grab works particularly well in coarse sediments up to cobble size, but tends to disturb the surface layer of soft oozes, as do all snapper samplers, thus limiting its biological uses in soft sediments.

Marukawa Grab (Rigosha Mfg. Co. Cat. 180; Tsurumi–Seiki Kosakusho Co., Ltd. Catalog). The Marukawa grab (Fig. 18) is pushed into the sediment by a weight mounted above the jaws. The jaws are pulled shut by spring action, much the same way as in the Birge–Ekman apparatus. This 9 kg sampler, which has a 300 cm^3 capacity, is widely used by the Japanese to depths of 500 m.

Smith–McIntyre Spring Loading Sampler—1/10 m^2 (SMITH and MCINTYRE, 1954). The Smith–McIntyre device (Fig. 19) is forced into the sediment by two springs acting on the axis of the semi-cylindrical jaws. As the sampler is retrieved, the hoisting line acts on levers to close the jaws. An accurate sample is enhanced because the springs will not be released unless the instrument rests squarely on the bottom. This grab was designed for use in rough weather and for hard sand bottoms. It seems to be even more efficient on hard bottoms than the van Veen grab and can function in weather when the van Veen cannot be employed (THORSON, 1957).

Lee Grab—0.56 m^2 (Lee, 1944). The grab used by LEE in his study of the bottom fauna of the Meneshma Bight is a heavy (135 kg) commercial "clamshell" bucket manufactured by the Hayward Company. In operation a single cable is fastened to and winds about a counter-balanced drum mounted in the frame of the instrument. When the cable is drawn taut, the drum revolves and closes the jaws. On release of tension, the drum rotates in the opposite direction to gape the jaws.

Gordeev Prism Grab (SNERZHINSKII, 1951). This unique apparatus (Fig. 20) operates on the jaw-biting principle and obtains a sample by means of an ingenious but complicated system of closing plates operated by levers. It takes a sample of uniform depth and the depth of bite can be varied by adjusting some of the plates. The large 90 kg model is capable of digging to a depth of 1/2 m.

Orange Peel Grab (PACKARD, 1918; SHEPARD and MOODY, 1953; HARTMAN, 1955). The "orange peel" grab (Fig. 21) consists of four sectors designed to take a hemispherical bite out of the bottom. The sectors are operated by a large wheel-and-sprocket mechanism within the upper framework, which may be operated by a second cable or by a slack release mechanism activated by a messenger. A canvas sleeve can be placed over the upper works to prevent washing out of the sediment. This sampler is not used in European investigations. It is a standard piece of equipment, manufactured in several sizes

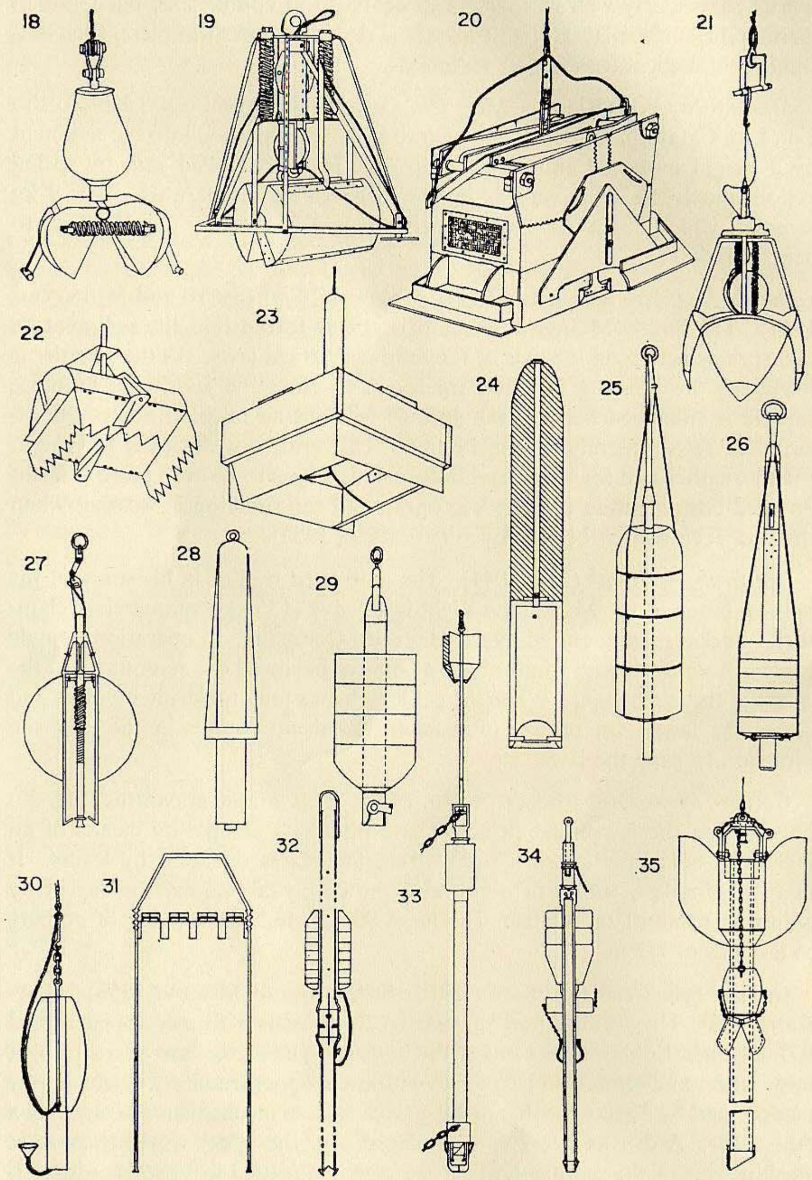

FIG.
18 Marukawa grab—Rigosha Mfg. Co. Cat. 180
19 Smith–McIntyre spring-loading grab—SMITH and MCINTYRE, 1954
20 Gordeev Prism grab—SNERZHINSKII, 1951
21 Orange peel grab—HOUGH, 1939
22 Allan grab—ALLAN, 1952
23 Kellen grab—KELLEN, 1954
24 Valve lead corer—MURRAY, 1885
25 "Hydra" corer—MURRAY, 1885
26 Baillie rod corer—MURRAY, 1885
27 Belknap–Sigsbee corer—AGASSIZ, 1888
28 Kitahara corer—Rigosha Mfg. Co. Cat. 180
29 Prince of Monaco's corer—THOULET, 1890
30 Cable-type corer—SNERZHINSKII, 1951
31 Lang corer—LANG, 1930
32 Emery–Dietz corer—EMERY and DIETZ, 1941
33 Ekman corer—SNERZHINSKII, 1951
34 "Meteor" corer—CORRENS, 1935
35 Zbekochernaz corer—SNERZHINSKII, 1951

to pull out caissons, pipes, etc., and it is recommended as a reconnaissance sampler only. According to THORSON (1957), the orange peel bucket should not be used in critical quantitative work that is to be compared with results of other regions. On the other hand, REISH (1959) described recent modifications of the Orange peel grab such as a new trigger mechanism and more efficient closing plates and states that a volume of sample to surface-area sampled relationship has been worked out.

Allan Grab (ALLAN, 1952). The Allan sampler (Fig. 22) is hand operated by a tube within the handle. The tube is pushed down to close the two jaws. The grab, which can be used to depths of 3.3 m, operates well in swift water and on sloping surfaces. It functions best in small gravel, silt, and clay, but it does not work well in large gravel or weed beds.

Kellen Sampler (KELLEN, 1954). The Kellen sampler is a shallow water, hand-operated device which consists of a 15 cm square by 5 cm deep wooden frame with aluminium flanges (Fig. 23). The flanges are pushed into the sediment and two of them are drawn shut by means of a wire which runs through the hollow handle. The apparatus has been used primarily in soft sediments.

CORING SAMPLERS

Gravity Corers

(Tubes, with trap valves on top and core retainers at the cutting end, which are driven into the sediment by encircling weight.)

Valve Lead Corer (MURRAY, 1885). This device (Fig. 24) is a modification of the mariners lead. The open end of the cylinder which is at the base of the lead is fitted with a butterfly valve that retains the sediment sample. The butterfly valve distorts the core by cutting it in two.

"Hydra" Corer (MURRAY, 1885). The "Hydra" corer (Fig. 25), which was used on the *Challenger* expedition, consists of a brass tube encircled by detachable weights, and fitted with a butterfly valve at its lower end. The core obtained is only a few inches long and stratification is distorted by the butterfly valve which cuts the core in half (HOUGH, 1934). The Baillie Rod (MURRAY, 1885), a similar device (Fig. 26), was used both on the *Challenger* and *Gazelle* expeditions and is capable of taking a short core 6.3 cm in diameter.

Belknap–Sigsbee Corer (AGASSIZ, 1888; SOULE, 1932). In the Belknap–Sigsbee instrument (Fig. 27), the lower valve consists of a spring-operated piston fixed to a rod in the center of the tube. The sample has to enter the tube through a constriction and pass around the piston. In so doing, the sediment sample is badly distorted. SIGSBEE's contribution to the device was the weight release mechanism which is an improved version of that found on Brooke's sampler (See MISCELLANEOUS SAMPLERS). SOULE (1932) described a more streamlined version which takes a longer core and the spring-operated core retainer is also used at the present time (Fig. 28) in the Kitahara sampler (Rigosha Mfg. Co. Cat. 180).

Prince of Monaco's Corer (THOULET, 1890). The Monaco sampler has a stopcock in the end of the tube (Fig. 29). The stopcock is open when the corer hits the bottom and the sample has clear passage into the tube. It is closed when the weights slide over a lever as they are detached. Only a very short core can be taken.

Cable-Type Corer (SNERZHINSKII, 1951). The cable-type apparatus (Fig. 30) consists of a short coring tube mounted on a rod, a funnel-shaped core retainer, and a removable weight. After the sampler is buried in the sediment, the sounding line is released from the rod and is free to pull the core retainer into position on hoisting. The weight is pulled off the free end of the rod and left on the bottom.

Lang Corer—1/40 m^2 (LANG, 1930). The Lang corer is a shallow water coring device designed primarily for obtaining a quantitative faunal sample from soft sediments. It consists of a weighted tube (50 cm high × 18 cm diam.) with five simple valves in the lid (Fig. 31). Care must be taken so that the sampler strikes the bottom in a vertical position. The device must also be hoisted smoothly or the sediment will jostle free, as the sampler has no core-retaining mechanism at its lower end. Once at the surface of the water, the sampler must be moved over a catch basin or straining net as soon as possible or the sample may start dropping out of the tube. It was felt by the designer that the deep penetration of the sampler tends to minimize the error in faunal count incurred by the loss of some sediment from the bottom of the tube.

Emery–Dietz Corer (EMERY and DIETZ, 1941). The Emery–Dietz corer (Fig. 32) consists of a shaft, weights, and coring tube. On the shaft over the valve housing is a set of removable lead weights which can be increased for deeper penetration. The valve consists of a rubber bung resting in guides and fitting loosely in a brass seating. The coring pipe, 5 or 6.3 cm in diameter, is set in a sleeve below the valve housing. A nose piece with a slightly smaller diameter than the coring pipe is screwed to the bottom end of the tube. Plastic strips fitted in the nose piece and bent towards the center of the tube serve as a core retainer. In operation, this 270 kg corer is free wheeled from 90 m above the bottom with only sufficient braking to ensure a vertical descent.

Ekman Corer (EKMAN, 1905). The Ekman device (Fig. 33), which has served as a prototype for other corers, has a steel collecting tube with a stationary lead weight near the upper end. An iron pipe with fins is attached at the top of the tube to keep the instrument upright during descent. For core retainers the sampling tube is provided with a check valve at the upper end and a pair of brass jaws that cover the lower end after the core has been taken. The jaws are connected by a short chain to a movable weight encircling the tube. The weight, in turn, is secured by a chain to a catch at the lower end of the fin pipe. When the corer hits bottom, the line becomes slack, and a sliding rod in the fin pipe slips downward and releases the chain holding the weight. The weight pushes the jaws down the coring tube, and they slip over the end when the ascending tube clears the bottom. This device works well in deep water and cores up to 2 m have been obtained. It does not do well, however, in swift currents. A problem with this corer, as with any other corer, is distortion of the sediment sample by compression. (For studies of core distortion see JUUL and HVORSLEV, 1949.) A similar coring device without stabilizing fins (Fig. 34) and for taking shorter cores (60 to 90 cm) was used aboard the German research vessel *Meteor* (CORRENS, 1935). The version employed in the U.S.S.R., the Zbekochernaz Tube (SNERZHINSKII, 1951), has a slightly altered tripping mechanism for the jaws and has fins attached directly to the coring tube (Fig. 35).

Mills Corer (MILLS, 1961). The Mills sampler has a simple check valve on top and an external mobile core-retaining mechanism. The core retainer (Fig. 36), which consists of two flexible metal strips mounted on the lower side of a free sliding collar, is released from the catches holding the retainer in place when the corer penetrates the sediment. On withdrawal, a sliding collar weight forces the retainer down the core barrel and it springs into place under the opening of the corer. This external retaining device was designed to avoid the disturbance of the surface layer of sediment which so frequently accompanies the use of internal core retainers.

Trask Corer (TRASK, 1927). The widely used Trask corer (HOUGH, 1939), which has seen considerable service, consists of a core barrel, 3.8 cm in diameter and up to 1.8 m in length, that is screwed into a check valve which in turn is fitted to a pipe of smaller diameter (Fig. 37). A T-connection can be fixed to the top of the pipe that will provide a place of attachment to the hoisting line and an escape route for water. The sampler is loaded with a variable number of pierced weights which encircle the upper pipe. For convenience of sample removal, core liners can be used.

Sjostedt Corer (SJOSTEDT, 1923). The Sjostedt corer (Fig. 38), which is 1 m long, has a lead weight, a pair of guiding fins near the upper end, and a vertical check valve at the top of the tube. Core barrel liners can be used with this sampler.

Woods Hole Corer (HOUGH, 1939). The Woods Hole corer was designed for bacterial work. It consists of a metal tube, with a glass liner 2.5 cm in diameter, which is weighted by a lead block. A check valve is located on an inverted U-shaped hoisting handle at the top of the block. The valve is connected to the glass tubing which extends above the lead block by means of a short length of rubber tubing. The device takes a 45 cm core.

"*Albatross*" *Corer* (SUMNER, LOUDERBACK, SCHMITT, and JOHNSTON, 1914) The Albatross corer (Fig. 39) was designed to eliminate the principle sources of trouble of the Ekman apparatus, i.e., the core-retaining mechanism and the instability of the load. It consists of two sections coupled together by wing nuts and bolts. The lower section has an inner and outer brass tube between which is the lead load. The core liner can be removed by uncoupling the two portions of the sampler. The core retainer at the bottom of the corer has a valve stopcock located in the cutting bit. On the upper section of the corer is a check valve and the mechanism of closing the stopcock. When the corer strikes the bottom, a movable rod connected to the hoisting line is carried by its momentum to free the closing mechanism release from a retaining catch. On hoisting, tension draws the rod back to its original position and closes the stopcock by means of a thin connecting rod running through the lead load. This sampler takes cores up to 2 m in length.

Strom Corer (STROM, 1934). The Strom device (Fig. 40) has a core-retaining valve resembling that of the "Albatross" and "Prince of Monaco" corers. The valve is shut by an outside lever which is pulled down by the resistance of the sediment when the corer is withdrawn. Designed for soft sediments, the shoulder of the weight prevents the apparatus from penetrating beyond the top of the corer.

Iselin Corer (ISELIN, 1932). The tube of this corer is square in cross-section and has one removable side (Fig. 41). Above the coring section the tube widens into a chamber which is perforated for water passage. The whole metal section (180 kg) is fitted to a 3 m wooden beam which is attached to a hoisting cable. There is a trap valve at the bottom of the corer which is locked by a slotted-key device until the sampler hits the bottom. When a strain is placed on the cable during hoisting, the valve is shut before the corer clears the sediment. Cores up to 2 m long can be taken.

Okamoto Corer (Rigosha Mfg. Co. Cat. 180). The Okamoto corer (Fig. 42) is unique in that rocks held in netting can be substituted for more expensive cast weights which frequently are left behind on the bottom. When the sampler strikes the sediment, the rings holding the netting slip off the supporting arms, thus freeing the rocks from the coring tube.

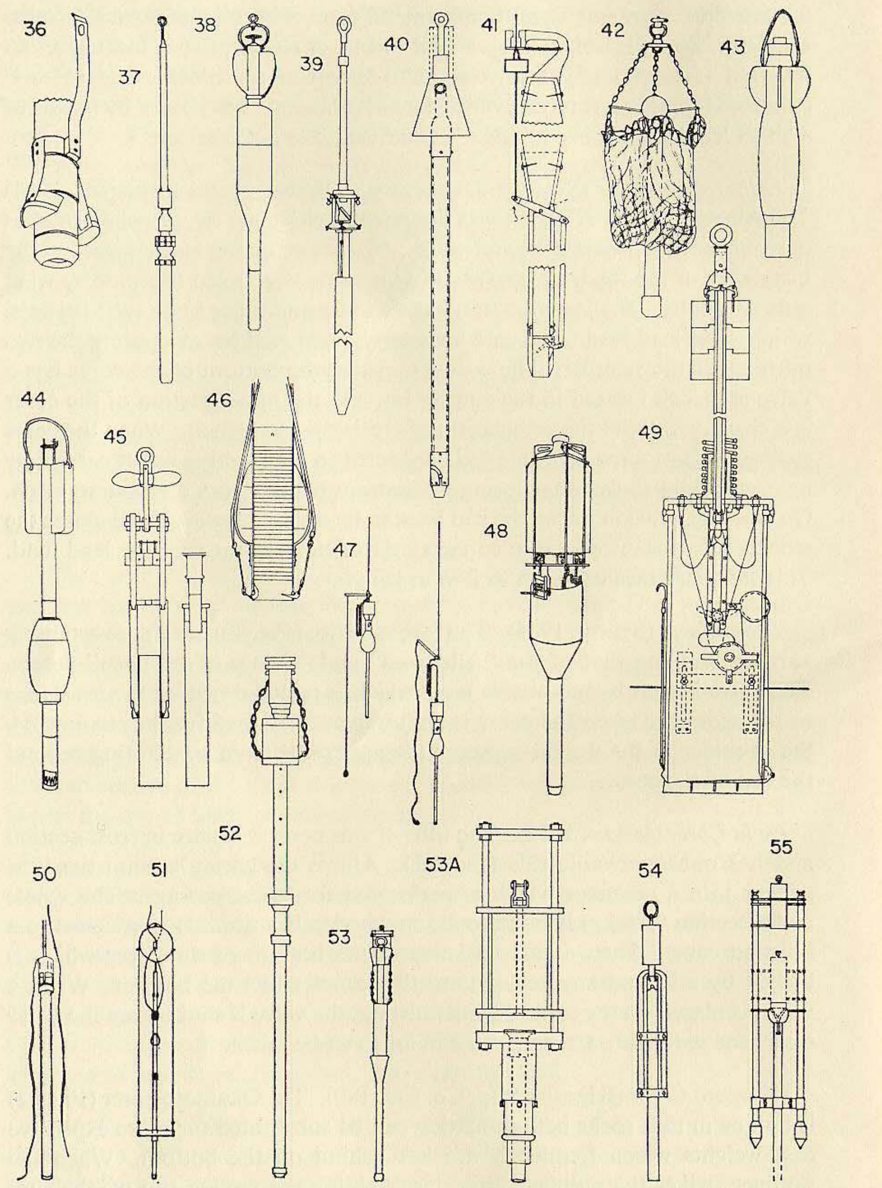

FIG.
36 Mills corer—MILLS, 1961
37 Trask corer—HOUGH, 1939
38 Sjostedt corer—SJOSTEDT, 1923
39 "Albatross" corer—SUMNER *et al.*, 1914
40 Strom corer—STROM, 1934
41 Iselin corer—ISELIN, 1932
42 Okamoto corer—Rigosha Mfg. Co. Cat. 180
43 Lundqvist corer—LUNDQVIST, 1925
44 Phleger corer—PHLEGER, 1951
45 Moore–Neill short corer—MOORE and NEILL, 1930
46 Enequist corer—THORSON, 1957
47 Hvorslev–Stetson free falling corer—HVORSLEV and STETSON, 1946
48 Moore free-corer—MOORE, 1961
49 Pettersson impact corer—HOUGH, 1939
50 Twenhofel impact corer—HOUGH, 1939
51 Varney "pile-driver" impact corer—VARNEY, 1935
52 Niino impact corer—Rigosha Mfg. Co. Cat. 180
53 Sjostedt impact corer—PRATJE, 1938
53a "Rammer lead" impact corer—STROM, 1934
54 Naumann impact corer—LUNDQVIST, 1925
55 Auerbach impact corer—LUNDQVIST, 1925

Lundqvist Corer (LUNDQVIST, 1925). This is a small gravity corer (Fig. 43) which has a glass plate check valve. The core liner can be removed by uncapping the top of the tube and removing the spring which holds the liner in position. Lundqvist has designed models for both deep and shallow water and for coarse as well as fine sediments.

Phleger Corer (PHLEGER, 1951). The widely used Phleger corer has a short weighted tube (18 kg) with a removable liner and a replaceable cutting edge (Fig. 44). Cores have been taken from depths of 4600 m from cohesive sediment. Good stratification is maintained, particularly in the surface layers (THORSON, 1957).

Moore–Neill Short Corer (MOORE and NEILL, 1930). The Moore–Neill sampler (Fig. 45) consists of a coring tube and a glass liner set in a brass cylinder. The top of the glass liner is plugged and cushioned against a metal plate in the brass cylinder by a perforated rubber bung. Tubing extends through the rubber bung to the glass plate check valve above. During descent the flow of water through the sampler forces the glass plate away from the opening of the tubing. During ascent the glass plate blocks this opening and holds the core sample by suction. A propeller is mounted near the top of the apparatus to ensure vertical descent.

Enequist Corer—100 cm² (ENEQUIST, 1941). This corer is a quadrangular tube-within-a-tube (Fig. 46). The outer tube, which is bolted to, but removable from, the liner, has two handles and a lead mantle. One side of the inner tube has slits at 1-cm intervals for partitioning the core. The core is retained by two flaps which are pulled down across the bottom of the corer when tension is placed on the retrieving line. This highly recommended apparatus (THORSON, 1957) functions well except in hard sand and gravel.

Hvorslev–Stetson Free Falling Corer (HVORSLEV and STETSON, 1946). The most noteworthy feature of the Hvorslev–Stetson corer is its free falling mechanism. This innovation permits a smooth penetration into the sediment which is free of any uneven tension that a heaving ship might transmit along the hoisting line. During descent the Hvorslev–Stetson corer and a coil of wire are suspended from one arm of a release mechanism while a counterweight hangs from the other arm (Fig. 47). The weight touches the bottom first and allows the corer to slip off the release and fall free under its own weight. A similar free falling corer is described by SYSOEV (1956) of the U.S.S.R. It is a heavily loaded tube (150 to 250 kg) which can take a core 5 to 6 m long.

Moore Free-Corer (MOORE, 1961). The free-corer (Fig. 48) is unique in that it does not require a winch and cable. Its components are a core barrel and check valve which fit loosely in a disposable weighted casing, and a buoyant

chamber mounted in a frame. The buoyant chamber assembly is held to the casing section by marine release-delay timers (VAN DORN, 1953). Drops with a prototype have shown that when the device is rolled over the side, it quickly rights itself and descends at a rate of 3.5 m/sec. In shallow water drops (18 m) an air-filled chamber is used while in deeper water (1250 m) a gasoline-filled buoyant chamber is substituted. The buoyant chamber, to which the core barrel is attached, is freed from the weighted casing after penetration of the bottom by the release-delay timers. The release-delay mechanism is held shut by a magnesium rod which runs through a compressed spring. When the rod snaps due to galvanic action, the spring is able to expand and force open the bottom of the release-delay timer. The buoyant chamber then draws the core barrel out of the concrete casing and ascends to the surface. The prototype has taken 3.5 cm diameter cores up to 60 cm long from silty sand bottoms. The corer is inexpensive to construct and is a practical device for smaller institutions which are unable to afford vessels with winches and heavy cable. Also, a series of cores can be obtained much more quickly and be placed much more accurately than is possible with cable operated samplers. Since this corer has no piston, there is a problem of core distortion. In addition there is the difficulty of locating the corer after it has returned to the surface. Dye patches at the drop site and readily visible (by eye or radar) flags attached to the chamber frame aid in recovery.

Impact Corers

(Corers which are hammered into the sediment pneumatically, by mobile weights, or by an explosive charge.)

Pettersson Impact Corer (PETTERSSON, 1928). The Pettersson corer is a quadrangular metal tube (Fig. 49) which is forced into the sediment by a 20 to 40 kg load sliding along a shaft. As it is being retrieved, a system of pulleys draws a horizontal shield across the bottom of the corer to act as a core retainer. This apparatus penetrates (15 cm) best in "mixed" bottoms to capture the deep-burrowing animals (THORSON, 1957). It does not operate well in sand and gravel bottoms. Consult EKMAN (1953) for suggested improvements.

Twenhofel Impact Corer (TWENHOFEL, 1933). This tube (Fig. 50) is driven into the bottom by a 11 kg lead hammer operated by an auxiliary line. The core receiver (7.6 cm diam. × 2 m long) has a valve on top and a cutting bit at the bottom. Supported above the tube are two solid brass cylinders with a 51 cm steel rod between them. The pierced 11 kg load is raised by the auxiliary line and allowed to fall on the lower brass cylinder. This action does not function well at great depths because of friction on the auxiliary line (HOUGH, 1939).

Varney "Pile-Driver" Impact Corer (VARNEY, 1935; HOUGH, 1939). The coring part of the Varney device is held upright on the bottom by a float. It is pounded into the sediment by a streamlined lead hammer that slides along the core tube (Fig. 51). Though cores up to 1.5 m long have been taken in shallow water, the cylindrical metal float collapsed when the apparatus was tried at depths below 60 m. (For modifications of this design consult TRENER and MORANDINI, 1939.)

Niino Impact Corer (Rigosha Mfg. Co. Cat. 180). The Niino corer (Fig. 52) is an impact sampler which is driven into the sediment by the action of a series of weights which encircle the upper portion of the instrument. The weights, when released by a messenger, slide down and strike a shoulder above the coring tube. This device is designed to take a 1.5 m long × 3.5 cm diameter core.

Sjostedt Impact Corer (PRATJE, 1938). The Sjostedt corer (Fig. 53), which has a check valve, is driven into the sediment by means of an encircling weight which can be repeatedly raised and dropped on a fixed shoulder of the coring tube. A device closely allied to the Sjostedt corer is the "Rammer Lead" (Fig. 53A) described by STROM. This corer, which can take cores up to 4 m in length, is driven into the bottom by a 30 kg weight operated by the hoisting line (STROM, 1934).

Naumann Impact Corer (LUNDQVIST, 1925). The popular Naumann sampler (Fig. 54) consists of a meter-long coring tube with a trap valve on top. The coring tube rides freely in weighted guides. When the sampler hits the bottom, the guides slide down on the tube until the weighted top of the guide frame strikes the top of the corer. By raising the guide frame and letting it fall freely, the tube can be driven into the sediment. A more elaborate version (Fig. 55) of this is the Auerbach impact corer (LUNDQVIST, 1925).

Perfelev Impact Corer (SNERZHINSKII, 1951). The Perfelev corer consists of movable and fixed weights and a coring tube (Fig. 56). The brass coring tube, 26 to 100 cm long, has a valve on top and is encircled by the fixed weights. Above the coring tube and the fixed weights is the frame on which the movable load rides. On contacting the bottom the hoisting line becomes slack and the movable weight slips down the frame to help drive the coring tube into the sediment and to seal the valve on top of the tube. This corer is reported to be very successful in shallow water.

Piggot Impact Corer (PIGGOT, 1936). The Piggot sampler (Fig. 57) is driven into the sediment by an explosive charge which is detonated when the sampler hits the bottom. The charge and cap are located in a heavy chamber above the coring tube. An auxiliary cable prevents the loss of the tube after

discharge. The brass-lined coring tube can take 3 m cores and has been operated successfully at a depth of 4500 m; however, since the sampler is expensive to construct and dangerous to operate, it is not used at present.

Multiple Tube Corers

(Weighted frames holding more than one core barrel.)

Krogh–Spärck Multiple Tube Corer (KROGH and SPÄRCK, 1936). The Krogh–Spärck apparatus consists of a central loaded shaft with six arms, each holding a coring tube (Fig. 58). These tubes (28 mm diam. × 50 cm long), which can hold plastic liners, have rubber check valves on top. The valves allow water to flow freely through them during descent, but are forced shut by water pressure during hoisting. Since there are no core retainers on the bottom of the tubes, adhesion and suction must serve to bring the samples aboard. The sampler operates optimally in mud of medium toughness and to function, each tube must be thrust 10 to 15 cm into the sediment (THORSON, 1957).

Multiple Tube Cable Corer (SNERZHINSKII, 1951). The multiple tube sampler (Fig. 59) has a weight-releasing mechanism similar to the cable type sampler. But, instead of a single core tube and cone-shaped core retainer, several tubes are substituted and the samples are held in the tubes by the suction of an overhead washer valve.

Jones Multiple Tube Corer—0.64 m^2 (Dr. M. L. JONES, Amer. Mus. Nat. Hist., personal communication). The Jones device is primarily a microfauna sampler which consists of 100 square (2.54 cm to a side) brass corers arranged in a square and held in place by a heavy frame. This sampler has been used to study the areal distribution of benthic organisms. Because of the tremendous friction resulting from the surface area presented by the edges and walls of the 100 corers, the sampler often has to be accompanied down and forced into the bottom by a skin-diver. It works best in sticky sediments and as yet there is no mechanism for preventing cores of less cohesive sediment from washing out on hoisting.

Hydrostatic Corers

(Cores which are (1) sucked into the sediment by the creation of a vacuum over the core or (2) forced into the bottom by the pressure differential between the air within the sampler and the surrounding water.)

Knudsen Suction Corer—1/10 m^2 (HOLME, 1953). The Knudsen corer is an iron cylinder, 30 cm high and 36 cm in diameter, which is open below and capped on top by an iron lid and a water pump (Fig. 60). When the sampler strikes the bottom, a lever falls, making the retrieving line ready for hauling. Tension on the hoisting line rotates a drum operating the water pump which

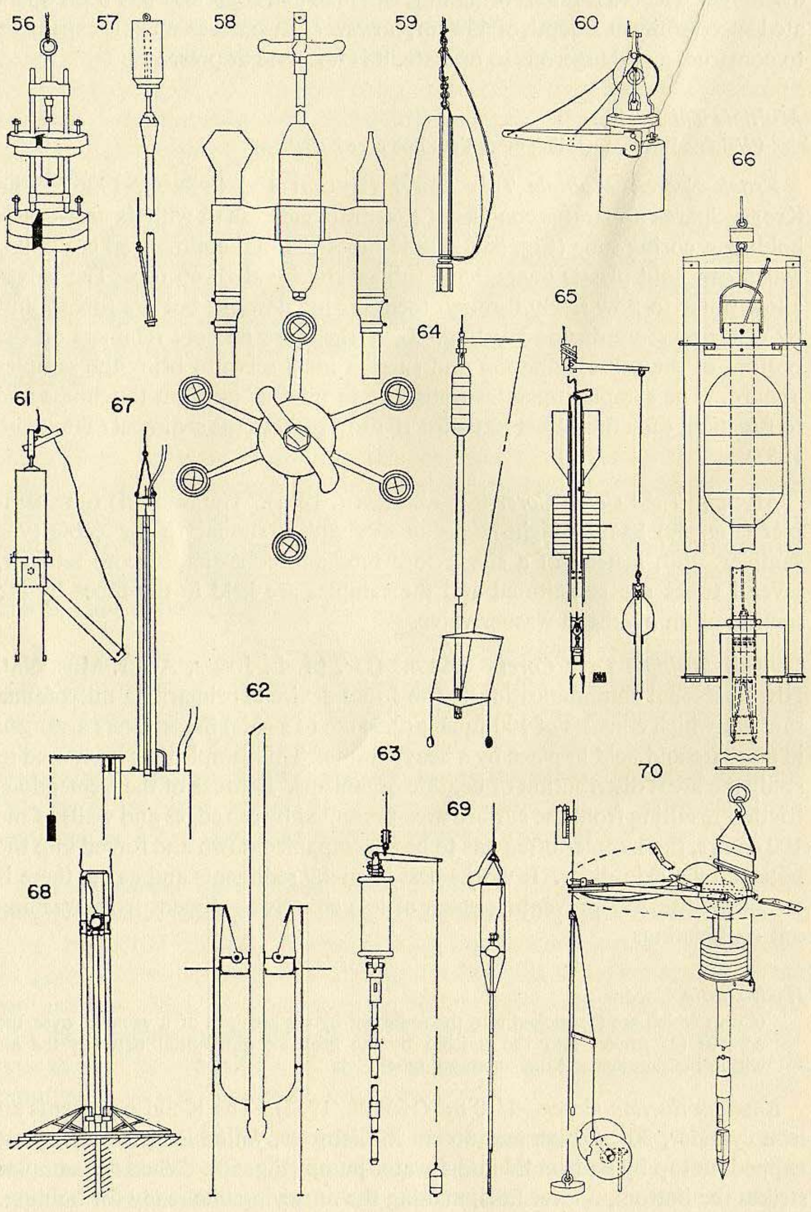

FIG.
56 Perfelev impact corer—SNERZHINSKII, 1951
57 Piggot impact corer—KRUMBEIN and PETTIJOHN, 1938
58 Krogh–Spärck "chandelier" multiple tube corer—KROGH and SPÄRCK, 1936
59 Multiple tube sounding corer—SNERZHINSKII, 1951
60 Knudsen suction corer—THORSON, 1957
61 Holme suction corer—HOLME, 1953
62 Varney–Redwine hydrostatic corer—VARNEY and REDWINE, 1937
63 Sysoev–Kudinov hydrostatic corer—BEZRUKOV and PETELIN, 1960
64 Kullenberg piston corer—SYSOEV, 1951b
65 Ewing–Ludas piston corer—DIETZ, 1952
66 Model TPR-51 piston corer—UDINTZEV *et al.*, 1956
67 Pneumatic piston corer—MACKARETH, 1958
68 Vibratory piston corer—BEZRUKOV and PETELIN, 1960
69 Jenkin–Mortimer core cutter—JENKIN and MORTIMER, 1938
70 Core cutter—JENKIN *et al.*, 1941

sucks the tube into the sediment. The retrieving line then comes free after rotating the drum and pulls again on the lever. As soon as the coring tube is clear of the sediment, it capsizes and is brought to the surface upside down. The corer collects up to 30 l. of material and maintains natural stratification. Though it performs well on hard level bottoms, the sampler is very heavy and is sometimes almost impossible to retrieve from soft bottoms (THORSON, 1957).

Holme Suction Corer—1/50 m^2 (HOLME, 1953). The Holme instrument (Fig. 61) has features of both the Hunt and Knudsen samplers. Suction is produced by hydrostatic pressure instead of by a pump. It penetrates on the average to 16 cm even in muddy sand and the stratification is rather undisturbed (THORSON, 1957).

Varney–Redwine Suction Corer (HOUGH, 1939). The Varney–Redwine device consists of a coring tube attached to a cylindrical chamber which holds air at atmospheric pressure. The chamber is shut before descent and when the tube enters the sediment, the seal between the coring tube and the chamber is broken. The pressure differential existing between the air and water pressure outside the chamber tends to force sediment into the tube. Laboratory data, however, seem to indicate that the apparatus draws its sample from a spherical area about the end of the tube; therefore, it does not obtain a true core.

Varney–Redwine Hydrostatic Corer (VARNEY and REDWINE, 1937). The Varney–Redwine apparatus, which was lost off Catalina Island in 1938, consisted of a coring tube passing through and attached to a piston sliding in an air-filled cylinder (Fig. 62). The piston was held near the upper end of the cylinder by catches which were released from the piston by a foot trigger mechanism. When the sampler struck the bottom, the piston was released and was free to move downward under water pressure. Water pressure acting on the piston forced the coring tube into the sediment. This instrument took cores 1 to 2 m in length and a model has been designed to take cores at depths of 6000 m (HOUGH, 1939).

Sysoev–Kudinov Hydrostatic Corer (BEZRUKOV and PETELIN, 1960). The Sysoev–Kudinov corer (Fig. 63) is forced into the sediment by its own weight and by hydrostatic pressure. It consists of a core barrel attached to a hollow cylinder with an air space exactly equal to the volume enclosed by the core barrel. When the corer comes within 5 or 6 m of the bottom, it is freed from the short end of the rocker arm by the counterweight tripping device. On contacting the sediment, a valve connecting the coring tube with the hollow cylinder is opened. Water from the core barrel is forced into the cylinder by the pressure differential existing between the surrounding water and air at atmospheric pressure in the cylinder. As water moves into the cylinder, it tends to draw sediment up into the tube and to force the corer into the bottom. This instrument takes cores up to 34 m in length and BEZRUKOV and PETELIN (1960) report that it can operate successfully at any depth. UDA (1959) states, however, that the hydrostatic corer does not perform well in firm sediments and is not used in routine work.

Piston Corers

(Tubes which are forced pneumatically by weight, or by vibrations into the bottom around an enclosed piston which remains stationary at the surface of the sediment.)

Piston Corer. The incorporation of a piston in corer design represented a major advance in marine geological methods. Since the mechanism's first appearance, the design has seen various modifications and is presently being employed in both shallow and deep waters by scientists of many nations. The description that follows is that of the original double counter-weight model of Kullenberg (KULLENBERG, 1947).

The Kullenberg apparatus (Fig. 64) consists of a loaded steel coring tube in 5 m sections which is lined with short lengths of brass tubing. Inside the brass coring tube is a piston which is held stationary by a steel wire leading to the hoisting line. The coring tube is held on the short arm of the release mechanism while the counterbalance weights rest on the longer arm. The paired counterbalancing weights, suspended through eyes in a horizontal bar fitted to the coring tube, maintain the center of gravity on the axis of the tube. When the weights, which hang down below the core barrel, strike the bottom, the lever is tripped and the tube falls into the sediment over the stationary piston. Since the piston remains immobile, it creates a partial vacuum above the top of the core sample. This reduces wall friction which would ordinarily result in core compression. The inner diameter of the nose piece is smaller than that of the brass liner in order to prevent distortion of the peripheral parts of the sample. This sampler has taken cores up to 21 m long and is the best apparatus available for undisturbed deep cores. Modifications of the Kullenberg corer are: the Ewing and Ludas (DIETZ, 1952) corer (Fig. 65); the EMERY and BROUSSARD (1954), and BADER and PAQUETTE (1956) immobile piston corers which are modifications of SILVERMAN and WHALEY'S (1952) shallow water piston sampler; and a piston corer (model TPR-51) described by UDINTZEV and LISITZIN (1956). The U.S.S.R. model (Fig. 66), like the Emery and Broussard device, is the result of an attempt to avoid the principal defect of the original Kullenberg corer of having the piston line directly connected to the hoisting line. This has in the past resulted in deformed cores particularly in the surface layers. The Russians have separated the piston line from the hoisting line by constructing a guide frame to which the piston line is attached. Another Russian innovation is a mechanism which prevents water pressure during descent from pushing the piston up into the tube.

Pneumatic Piston Corer (MACKARETH, 1958). Mackareth's pneumatic piston corer employs compressed air to force the corer into the sediment and the Kullenberg piston device to reduce core compression. It consists of a movable coring tube inside a casing, and a hollow anchor chamber at the lower end of the device (Fig. 67). As soon as the instrument reaches the bottom, water is withdrawn through a hose from the anchor chamber thus sucking it into the sediment. Compressed air is then piped into the top of the outer casing to act on a piston at the top of the core tube. The tube is forced into the sediment around a smaller piston which fits within the coring tube and remains stationary at the surface of the sediment. When the top of the larger piston holding the core tube clears a connection joining the outer casing and the anchor chamber, air rushes into the anchor chamber to eject the sampler from the sediment and float it to the surface. This portable corer, which was designed for deep fresh water lakes, has functioned at depths of 250 m and takes 6 m cores. It can also be operated from a skiff. (For recent modifications consult SMITH, 1959.)

Vibratory Piston Corer (KUDINOV, 1957; BEZRUKOV and PETELIN, 1960). The vibratory piston corer (Fig. 68) is worked into the sediment by its own weight and by the vibrations of an electric motor. The vibrator is a 27 kW motor driven by a shipboard 220–380 V portable power plant. When on the bottom, the sampler rests on a hexagonal base. Arising from the base is a tubular frame joined by a cross-piece on top. Within the tubular frame is the vibrator which rides on the frame by means of guides. Attached under the vibrator is the core barrel within which is a piston. The piston is immobilized by a cable running to the cross-piece on top of the frame. The action of the vibrator permits undisturbed cores up to 4.5 m long to be taken from coarse sand and even gravel bottoms. To simplify the removal of the core from the tube, the core barrel can readily be detached from the vibrator and swung out from the frame to the horizontal position.

Core Cutters

(Devices which cut and enclose a core of sediment by means of a rotating portion of the coring tube.)

Core Cutter (JENKIN, MORTIMER, and PENNINGTON, 1941). The core cutter (Fig. 70) has an outer casing in the form of a tube, part of which is cut away and replaced by a face plate. An inner half-tube, the cutter, is supported on a shaft which rotates the cutter through a slit at the side of the face plate to slice into the sediment and enclose a sample. The cutter, which is triggered by a messenger on a separate line, is moved by rubber bands, swinging arms, and a gear system. This device takes cores 1.3 m in length and has been used in lakes to depths of 65 m. It is winch operated and weighs a minimum of 90 kg.

Jenkin–Mortimer Core-Cutter (JENKIN and MORTIMER, 1938). The Jenkin–Mortimer device is an earlier model than the cutter described above, differing mainly in the mechanism that rotates the cutter (Fig. 69). Tension on the hoisting line turns a disk which rotates the shaft on which the cutter is mounted. This device takes 1.2 m cores and can operate at great depths.

Manual Corers

(Corers, with or without pistons, which are worked by hand into the sediment.)

Livingston Manual Piston Corer (LIVINGSTON, 1955). The Livingston corer (Fig. 71), which employs the Kullenberg piston principle, consists of a thin-walled aluminum tube and a removable liner attached to a jointed extension rod. Inside the coring tube is a close-fitting piston which is attached to a steel cable. The tube is pushed into the bottom by the jointed rod while the piston remains stationary at the surface of the sediment. This sampler, which was designed for use in lakes, can be operated by one man in calm weather. It takes meter-long cores which are not distorted by compression. However, it functions only to depths of about 20 m, it does not penetrate tough or gravel sediments well, and the jointed rod tends to bend, even when surrounded by some sort of casing. A similar manual piston corer (Fig. 72) for use in shallow water, which is made of standard plumbing items, has been described by REISH and GREEN (1958).

Vallentyne Manual Piston Corer (VALLENTYNE, 1955). The Vallentyne sampler (Fig. 73) uses a piston to reduce core distortion and a rod and locking mechanism (see the Davis Peat Corer below) to permit subsurface coring. To take a surface core the sampler is lowered until the piston at the bottom of the instrument touches the sediment. The piston line is then clamped fast to immobilize the piston. The jointed rod attached to the sampler is used to force the core barrel into the sediment around the piston. (VALLENTYNE states that his design also permits the use of a falling weight to force the corer through tough sediments.) To procure a subsurface sample the core barrel is forced into the sediment to the desired depth with the piston blocking the lower entrance of the core barrel. The jointed rod and a catch mechanism are then pulled up in the barrel, away from the piston, until the catch engages near the top of the barrel. Next the piston is immobilized and the barrel is forced down around it. An undesirable feature of this sampler is that both a lowering line and a piston line are necessary, and these may entangle within the casing.

Larson Manual Corer (NAUMANN, 1925). The Larson corer consists of a tube, with a check valve on top, attached to the bottom of a long handle (7–8 m) (Fig. 74).

Smidt Hand Corer (SMIDT, 1951). The Smidt device (Fig. 75) consists of a short core barrel, with a rubber check valve on top, mounted on a shaft. The core barrel is of the same design as those of the Krogh–Spärck Chandelier Sampler.

Hanna Manual Corer (HANNA, 1954). The Hanna manual corer is a 7.6 cm diameter brass tube with a plastic liner held in place by an aluminum tube inserted from above (Fig. 76). A removable rubber ball check valve is placed in the top of the plastic liner before coring, thus eliminating the need of a core catcher at the bottom of the core tube. This sampler, which can be operated either from a skiff or afoot by two men, takes cores up to 2.1 m long.

Ginsburg and Lloyd Manual Piston Corer (GINSBURG and LLOYD, 1956). The Ginsburg and Lloyd corer, which can be constructed of tubes of various diameters and materials (plastics, aluminum, etc.), is operated in shallow water under a tripod (see BYRNE and KULM, 1962, for a description of a less elaborate monopod piston support) which supports a stationary piston on a cord from its apex. In operation the piston is lowered in the tube to the surface of the sediment, then the corer is forced into the sediment by an adjustable handle. The device has taken cores up to 2.1 m in length.

G. M. Manual Impact Corer (G. M. Mfg. Co. Bull. A). The G. M. hand corer has a heavy steel tube with a removable cutting head and a check valve on top, a 1.2 m plastic liner tube with a core catcher, and a heavy sliding weight with handles (Fig. 77). In operation the tube is held vertically and the sliding weight is pulled upward and allowed to fall free on a shoulder. By successive impacts the tube is forced into the sediment. The tube is 1.7 m long, 4.4 cm in diameter and weighs 8 kg. This sampler is not only useful in shallow water, but it also can be employed by skin-divers in greater depths.

Rittenhouse Manual Corer (HOUGH, 1939). The Rittenhouse corer is a 1.2 m length of 3.8 cm diameter pipe which has a reducing coupling on top and a cutting edge at the bottom. To remove the corer from the sediment without losing the sample, that part of the tube extending above the sample is filled with water and the pipe is sealed by placing a hand over the reducing coupling.

Banks Manual Corer (HOUGH, 1939). The Banks corer consists of a 61 cm section of 3.8 cm diameter pipe attached to a 1.9 cm diameter pipe handle. The length of the handle can be varied by adding sections. The bottom of the corer is reamed to give it a penetrating edge. To prevent the loss of the sample, a plate suspended by wires attached to the top of the corer covers the bottom of the tube after it has been withdrawn from the sediment. This sampler has been operated successfully from bridges.

Canal Manual Corer (FORTIER and BLANEY, 1928). The Canal sampler is a brass tube, 2.7 cm in diameter × 15.2 cm long, with a steel cutting edge (Fig. 78). It is loaded by a cone-shaped weight and is attached to a handle of variable length. The corer is pushed into the sediment up to the shoulders of the cone; the pipe is filled with water, and then a cap is screwed on the handle to create the suction necessary for the retention of the sample.

Davis Manual Peat Corer (BASTIN and DAVIS, 1909). The Davis sampler was originally designed for coring sub-surface peat deposits, but it has since been modified by TRASK (1932) for shallow water sediments. The principal parts of this device are a tube and a plunger (Fig. 79). A sample is obtained by forcing the apparatus into the sediment to the depth desired with the plunger blocking the entrance of the coring tube. Next the plunger is drawn up into the coring tube until a catch engages to secure it in its new position. The whole device is then forced deeper into the bottom to obtain the core. It has taken samples 7 m deep in mud in 5 m of water (HOUGH, 1939).

Kindle's "Seedtester" Manual Corer (HOUGH, 1939). This shallow water apparatus consists of two brass tubes, one fitting closely inside the other, which are pierced by slits at regular intervals. The corer, which requires a cap for core retention, can take a 1.5 m sample. The core can be examined immediately by revolving the outer tube 90° and lining up the slits of the two tubes.

Dendy Inverting Manual Corer (DENDY, 1944). The Dendy inverting corer is a hand-operated corer (Fig. 80) which can be manipulated from afoot or from a skiff. The sampling cup is a 7.8 cm diam. by 13 cm long cylinder with a fine mesh brass screen on one end. The cup is hinged to the bottom of the handle so that it can be rotated 180° upwards by a draw rope. The sampler is pushed into the sediment up to the brass screen. Tension on the draw rope removes a locking pin and rotates the sampler so that it is retrieved with the brass screen down. This sampler operates well in mud, sand, and fine gravel and it is particularly useful in loose watery sediments that will not remain in a coring tube (WELCH, 1948).

Combination Water–Sediment Samplers

(Sediment samplers provided with tubes, bottles, or special chambers for collecting water samples near or at the sediment–water interface.)

Combined Water and Bottom Sampler (NAUMANN, 1925). This sampler (Fig. 81) collects sediment in a cone on the bottom of a rod. Two water bottles are secured in baskets located on a crossbar farther up the rod. When the cone is buried in the sediment, a messenger is sent down the line which causes the stoppers to be extracted from the bottles.

Buchanan Combined Water Sampler and Bottom Corer (MURRAY, 1885). The Buchanan sampler (Fig. 82) consists of a coring tube and core retainer, and a water chamber for procuring a water sample immediately above the bottom. The water chamber has a check valve at either end which allows water to pass freely through the coring tube and chamber during descent. The apparatus is loaded by an encircling weight which becomes detached when the sampler strikes the bottom. A more recent version (Fig. 83) described by SNERZHINSKII (1951), has a ball check valve immediately over the coring tube and a more streamlined weight.

Hjort–Ruud Combined Water Sampler and Bottom Corer (HJORT and RUUD, 1938). The Hjort–Ruud instrument is a coring tube, 15.5 cm in diameter, with a rubber ball check valve on top and a bundle of glass tubes within for taking water samples 2, 10, 15, 20, and 30 cm above the bottom. For core removal the check valve on top of the apparatus is unscrewed and the tube is lowered over a pillar which pushes the sediment out through the top. This sampler operates well at depths of 200 m, but only sediments of a certain toughness will adhere (THORSON, 1957).

Scoop Samplers

(Samplers which scoop sediment out of the bottom with a rotating container.)

Fitzgerald Sediment Scoop (THOMSON, 1878). The Fitzgerald sampler (Fig. 85) has a cup on the end of a weighted lever arm which is held upright by a toggle. When the device contacts the bottom, the lever arm is released and the cup rotates through the sediment about a pivot until it contacts the cup cover plate. The sampler is retrieved by a chain attached to the cover plate. The lever arm, trailing behind, forces the cup against the cover plate to minimize sample washing. Unfortunately, the instrument takes only a small sample (HOUGH, 1939).

Holme Mud Scoop—1/20 m^2 (HOLME, 1949). The Holme device obtains a sample by a scoop rotating 180° on an axle which is mounted on a heavy weighted frame (Fig. 86). A release mechanism transfers tension from the frame to a rope wound around a large drum. The rotation of the drum, acting through a series of pulleys, draws the scoop through the sediment. This device takes a 3–4 l. sample, four times that of the standard Petersen grab (BARNES, 1959). However, the Holme scoop, which must be winch-operated, does not function well in rough seas or on sandy bottoms. Both single and double scoop models have been designed. The advantage of the two scoop sampler (Fig. 87) is that the scoops rotate towards each other, whereas the one scoop model tends to slide across the bottom as the single scoop digs in (HOLME, 1953).

Stetson–Iselin Scoop (HOUGH, 1939). The Stetson–Iselin instrument obtains bottom material by means of a curved tube that cuts the sediment and seals it so that there is no loss of sample on retrieving. The tube is rotated by gears activated by unreeling wire wrapped around a drum. The parts are mounted on a pipe frame and the weight comes to approximately 45 kg. HOUGH (1939) regards this as a very useful sampler.

Suction Samplers

(Devices which suck in loose sediment by vacuum or by the pressure differential between air within the sampler and the surrounding water.)

Holme Suction Sampler (HOLME, 1955). The Holme sampler (Fig. 88) employs the pressure differential established between air within the sampler and the outside water pressure to force sediment into the collecting tube. It consists of a sampling funnel and tube, a sample receiving chamber, and a plug held by hooks in the aperture connecting the sampling tube and the chamber. When the funnel strikes the bottom, it forces up the sliding shoulder on which the base of the hooks rest. The plug is freed from the hooks and is forced into the chamber by the pressure differential. The sediment follows the plug, and once in the chamber, sediment loss is prevented by a trap tube. The apparatus does well on sandy bottoms, but no sample stratification is preserved.

Hunt Suction Sampler (HUNT, 1926). This device (Fig. 89) operates on the same principle as the Holme suction sampler except that the connection between the sample chamber and the sampling tube is hermetically sealed by a glass plate. The apparatus has a bell-shaped intake (7.5 cm diam.) on the end of a sampling tube, and a sample chamber with a trap tube. When the bell strikes the bottom, the sampling tube is forced up and a metal projection within the tube smashes the glass plate, thus allowing sediment to be sucked up into the sample chamber through the trap tube. The sampler works well in the depth range of 10 to 70 m, but sample stratification is not maintained (THORSON, 1957).

Renn Suction Sampler (HOUGH, 1939). The Renn suction apparatus has an evacuated bottle with a projecting glass tube that has been sealed by heating while connected to an air pump. When the sampler contacts the sediment, the glass tube, which projects below the metal frame holding the bottle, penetrates a short distance into the bottom. The top of the glass tube is then knocked off by a spring-operated lever. This instrument was designed for bacteriological studies and performs best in loose fine-grained sediment.

Ooze Suction Sampler (WELCH, 1948). The ooze sampler consists of a rubber bulb attached to a funnel mounted in a frame (Fig. 90). When lowering, the bulb is compressed by two flat plates. When the ring at the base of the frame is resting on the bottom, a messenger is sent down which frees and allows the arms holding the plates to swing out. The bulb expands and sucks up ooze through the brass screen at the bottom of the funnel. The apparatus, which is useful in qualitative but not quantitative work, can be used with interchangeable screens and funnels. It is reported to be a rather delicate instrument.

Purasjoki Suction Sampler (PURASJOKI, 1953b). The Purasjoki sampler (Fig. 91) which operates on the same principle as the ooze sucker, is designed to draw in animals at and near the sediment–water interface. The sample is sucked up through a funnel and trap tube by the expansion of a chamber. When a messenger releases the rods holding down the top of the chamber, a spring contracts and raises the top of the chamber to create a vacuum. For removal of the sample, the funnel and trap tube are unscrewed and replaced by a rinsing tube. The chamber is then pumped clean.

UNDERWAY SAMPLERS, BUCKETS AND ROCK DREDGES

(Devices which are dragged across and dig into the bottom to obtain a sediment sample.)

"Scoopfish" Underway Bottom Sampler (EMERY and CHAMPION, 1948). When the torpedo-shaped "scoopfish" is lowered, the towing arm is towards the rear, thus directing the nose downward for digging in the bottom. On contact with the bottom, a removable sample cup in the nose is pushed back and trips the catch on the cover plate, which then snaps shut. This action frees the towing arm so that the nose is kept forward during retrieving. The Emery and Champion model (Fig. 92) is 38 cm long and weighs 5 kg. This sampler operates well to depths of 180 m and collects mud, sand, and to a lesser extent, gravel and rock (BARNES, 1959). A similar device employed in the U.S.S.R. is the Avilov underway sampler (SNERZHINSKII, 1951) which can procure samples at speeds of 8–10 knots (Fig. 93). The Worzel Underway "BT" sampler (WORZEL, 1948) is another widely used underway sampler (Fig. 94) that has been reported to be effective to depths of 75 fathoms.

Mann Bucket (HOUGH, 1939). The Mann sampler is merely a cylindrical iron tube (Fig. 95), 10 cm in diameter and 15 cm long, which is closed at one end and is attached to the sounding line at the open end (TRASK, 1932). A modification of this is a 10 cm in diameter × 30 cm long iron tube with a tough sac (made from rubber inner tubing) on the after end. A 4.5 kg weight is placed ahead of the dredge to give a low angle of drag (STETSON and SCHALK, 1935). Other modifications of the Mann sampler are represented by the Emery "pipe" (G. M. Mfg. Co. Bull. A) (Fig. 96) and the Bergmann Mud Bucket (F. Bergmann K-G cat.) (Fig. 97).

Robertson Mud Bucket (CLARK and MILNE, 1955). The Robertson sampler is a cylindrical bucket 20 cm in diameter and 38 cm long. The bucket lies on its side and the sharp edge of the open end cuts downward at an angle until the bucket is filled. The volume of sediment taken is about 8 l. and the bucket fills in the same way at all depths irrespective of the angle of the dragging rope. This sampler collects a disproportionately large number of organisms living just below the surface of the sediment, though it does allow reasonably accurate estimates of relative population densities. A similar apparatus is the HOUGH (1939) sheet-iron dredge, a rectangular iron box attached to a bailing strap. It is capable of obtaining a 14 l. sample.

Gilson Bucket (GILSON, 1906). This is a hemispherical scoop, 20 cm in diameter, fixed to an iron rod. When the device is retrieved, a lid, operated by a complicated mechanism, falls down to prevent the washing out of the sample. The instrument operates best in fine grain sediments and shallow water (HOUGH, 1939).

Lugn Sampler (LUGN, 1927). This sampler (Fig. 98) has two weights attached to a central stem and a loose fitting cup which rests on the lower weight. The weights are designed so that the apparatus scoops a sample (170 cm^3) from a uniform depth. The sampler weighs 5 kg and is approximately 50 cm long.

Rock Dredges. These are metal frames fitted with heavy bags that are designed for collecting rock for geological research. It has been found that the dredges can also retrieve almost any kind of sediment except loose sand and watery mud. Examples of heavy duty sediment dredges equipped with a sack are the SK (Tsurumi–Seiki Kosakusho, Co. Ltd. Cat.) (Fig. 99), and the Kumada (Fig. 100) and Niino (Fig. 101) (Rigosha Mfg. Cat. 180) type dredges.

MISCELLANEOUS SAMPLERS

Cuplead Sampler (MURRAY, 1885). The Cuplead sampler (Fig. 102), used on the *Challenger* expedition, is a hollow cone, fitted with a sliding lid, which is on a weighted spike. The lid prevents loss of the sample during ascent.

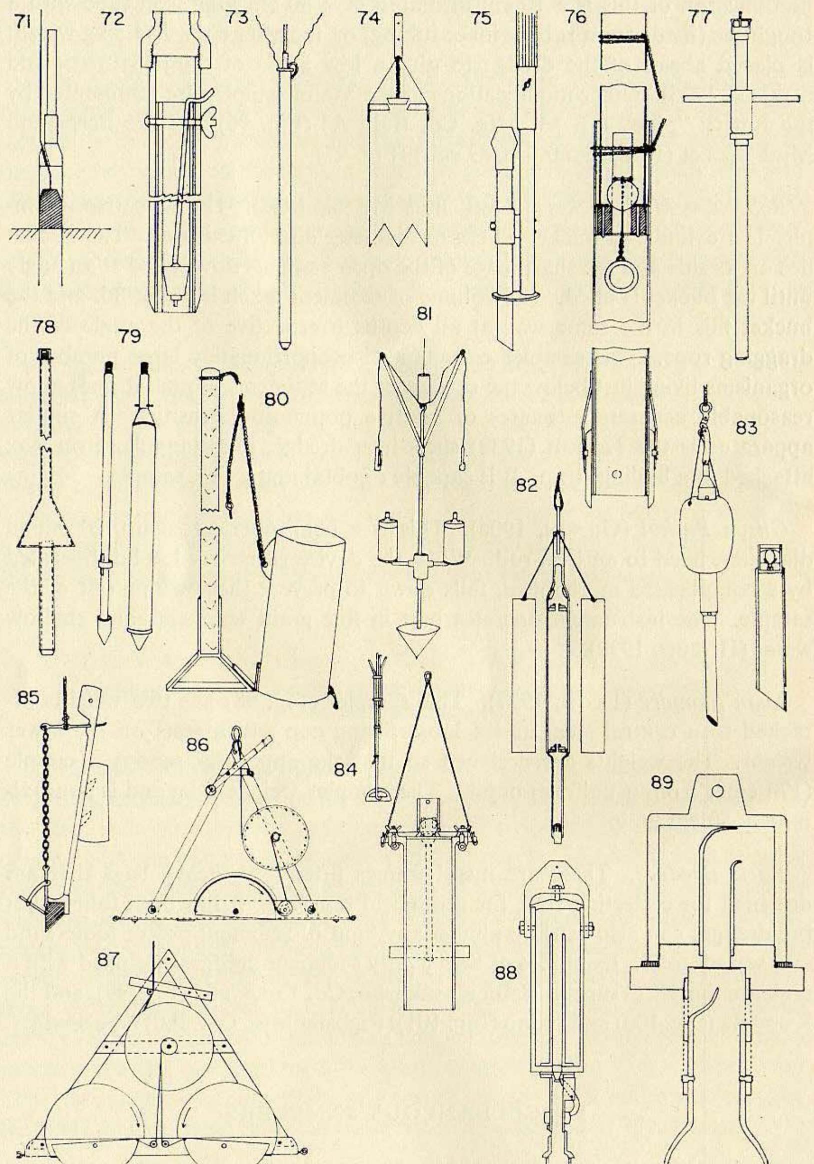

FIG.
71 Livingston manual piston corer—LIVINGSTON, 1955
72 Reish–Green manual piston corer—REISH and GREEN, 1958
73 Vallentyne manual piston corer—VALLENTYNE, 1955
74 Larson manual corer—NAUMANN, 1925
75 Smidt manual corer—SMIDT, 1951
76 Hanna manual corer—HANNA, 1954
77 G. M. manual corer—G. M. Mfg. Co. Bull. A.
78 Canal manual corer—HOUGH, 1939
79 Davis manual peat corer—HOUGH, 1939
80 Dendy inverting manual corer—DENDY, 1944
81 Combined water and bottom sampler—NAUMANN, 1925
82 Buchanan combined water sampler and bottom corer—MURRAY, 1885
83 Modified Buchanan sampler—SNERZHINSKII, 1951
84 Hjort–Ruud combined water sampler and bottom corer—HJORT and RUUD, 1938
85 Fitzgerald sediment scoop—THOULET, 1890
86 Holme mud (single) scoop—HOLME, 1949
87 Holme mud (double) scoop—HOLME, 1953
88 Holme suction sampler—HOLME, 1955
89 Hunt suction sampler—HOLME, 1955

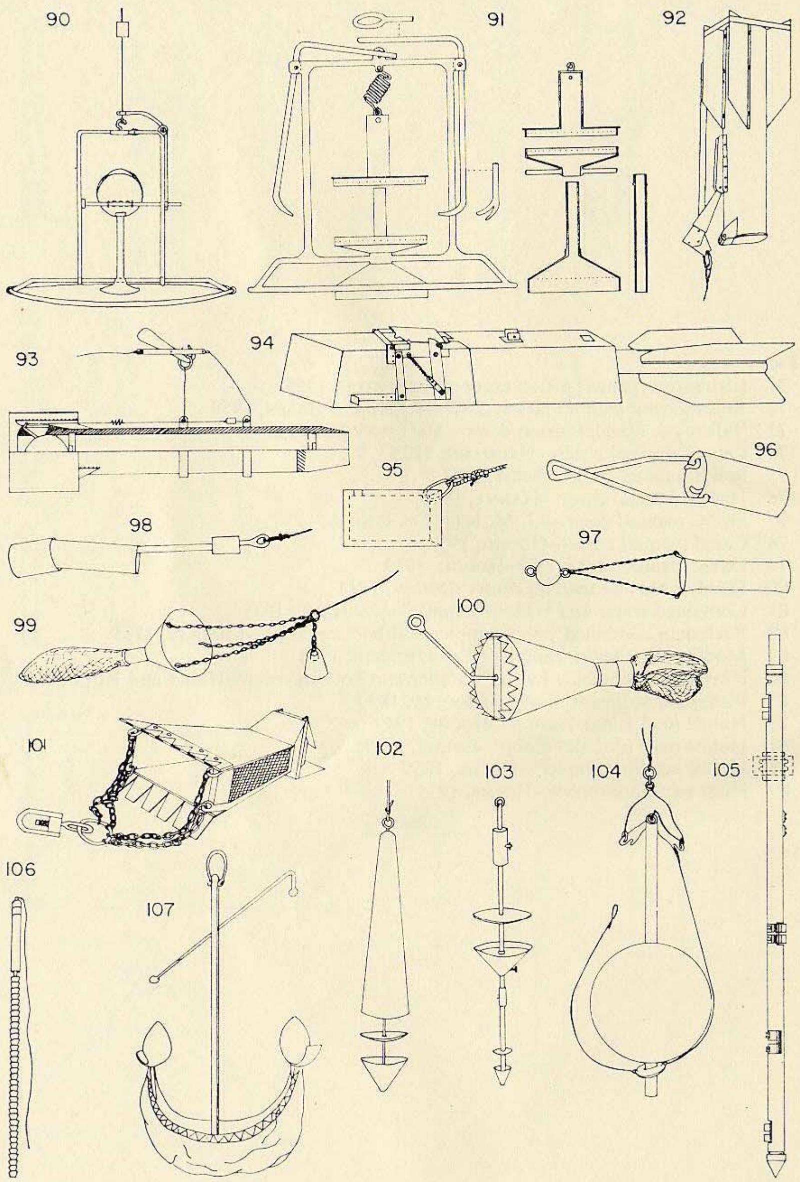

FIG.
90 Ooze suction sampler—Welch, 1948
91 Purasjoki suction sampler—Purasjoki, 1953b
92 Scoopfish underway bottom sampler—Barnes, 1959
93 Avilov underway bottom sampler—Snerzhinskii, 1951
94 Worzel "BT" underway bottom sampler—Worzel, 1948
95 Mann bucket—Hough, 1939
96 Emery "pipe" bucket—G. M. Mfg. Co., Bull. A
97 Bergmann mud bucket—F. Bergmann K-G Cat.
98 Lugn sampler—Lugn, 1927
99 SK rock dredge—Rigosha Mfg. Co. Cat. 180
100 Kumada rock dredge—Rigosha Mfg. Co. Cat. 180
101 Niino rock dredge—Rigosha Mfg. Co. Cat. 180
102 Cuplead sampler—Murray, 1885
103 Modified cuplead sampler—F. Bergmann K-G Cat.
104 Brooke's sounding device—Thomson, 1878
105 Ellms sampler—Ellms, 1931
106 "Spud" sampler—Hough, 1939
107 Modified anchor—Murray, 1891

Modifications of this sampler (Fig. 103) are still widely used today and are manufactured by several companies.

Brooke's Sounding Device (THOMSON, 1878). The famous sampler (Fig. 104) designed by Brooke in 1854, consists of an iron rod which passes through a pierced iron shot. The sampler picks up sediment in a wax lined cup on the bottom of the rod. When the instrument contacts the bottom, a simple release mechanism frees the thongs holding the shot, which is left behind on the bottom.

Emery Bacterial Sampler (EMERY, 1958). The Emery bacterial sampler device collects a sediment sample in a glass vial filled with sterile sea water. When the foot of the sampler strikes the bottom, a closing plate, blocking the opening of the invested vial, is momentarily flipped away by a combination of spring and cam action, thus permitting the entry of a small sediment sample. The sampler is retrieved with the closing plate back in place across the opening of the vial. This successful device functions at great depths and takes a sample from the thin top layer of sediment which is not contaminated by the overlying water.

Ellms Sampler (ELLMS, 1931). The Ellms device (Fig. 105) is a tube within a tube with the inner casing being divided into compartments by wooden spacers. The sampler is driven into the sediment by a handle of variable length. When the inner casing is twisted 180°, openings to the outside are lined up, and sediment enters removable cups in the compartments. A fixed fin on the outer steel casing prevents rotation in soft sediments. This device permits the collection of samples at various known depths in the sediment.

"Spud" Sampler (EAKIN, 1936). The Spud sampler is a rod with cup-like grooves located along the length of the rod at 3-cm intervals (Fig. 106). It works well in shallow water, but the cups generally do not collect sufficient sediment for mechanical analysis (HOUGH, 1939).

Soil Auger (HOUGH, 1939). The soil auger is an auger bit with a handle that can be increased in length by adding sections of pipe. The auger, which can be operated from a skiff, is screwed into the sediment to the desired depth by twisting a cross-piece on the end of the handle. For removal a wrench is placed on the handle at gunwhale level and the skiff is rocked. This sampler has been operated successfully in 12 m of water. It does not work well in sand.

Modified Anchors (MURRAY, 1891; SHEPARD, TREFETHEN and COHEE, 1934; HOUGH, 1939). Anchors, which can be modified by supplying cup-like flukes (Fig. 107), will pick up any fine-grained deposit that is sufficiently sticky to adhere to the flukes. Such modified anchors have been found to be particularly useful when clay is overlain by loose gravel.

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APPENDIX I

The following is a list of organizations which manufacture or lend bottom samplers. This information was obtained from advertising brochures and from PRATT, ALLEN, ISAACS, and WELCH (1949, 1953), THORSON (1957), and RYTHER, YENTSCH, and LAUFF (1959).

Manufacturer	*Apparatus*
Askania-Werke A. G. U.S. Branch Office 4913 Cordell Avenue Bethesda, Maryland	"Scoopfish" Underway Sampler Gravity Corer
Bergen Nautik Strandgt. 18 Bergen, Norway	Petersen Grab Ekman Type Corer
Eberbach Corporation Ann Arbor, Michigan	Davis Peat Corer
Extruded Plastics Incorporated New Canaan Avenue Norwalk, Connecticut	Plastic Core Liners
Foerst Mechanical Specialties Company 2407 N. St. Louis Avenue Chicago 47, Illinois	Ekman Grab Petersen Grab Gravity Corer (short)
Franz Bergmann–K-G Berliner Strasse 25 Berlin-Zehlendorf, Germany	Birge–Ekman Grab Naumann Corer Mud Bucket Cup Lead
G. M. Mfg. Co. 12 East 12th Street New York 3, New York	Birge–Ekman Grab LaFond–Dietz Grab Bottom Snapper Grab
Kahl Scientific Instrument Corp. P. O. Box 1166 El Cajon, California	Phleger Corer Kullenberg Corer G. M. Hand Corer "Scoopfish" Underway Sampler Mud Bucket (Emery Type)
The Hayward Company 50 Church Street New York 7, New York	Orange Peel Grab Clamshell Bucket
Hyaline Corporation 909 North Capitol Indianapolis, Indiana	Plastic Core Liners
Hydro-Bios Apparetebau GmbH Wismarer Strasse 14 Kiel, Germany	van Veen Grab Ekman Grab Gravity Corer (short) Naumann Impact Corer
Hytech Corporation "G" Street Pier San Diego 1, California	Orange Peel Grab