

A multiple corer for taking virtually undisturbed samples from shelf, bathyal and abyssal sediments

Corer (multiple)
Undisturbed cores
Shelf sediments
Bathyal sediments
Abyssal sediments
Carottier (multiple)
Carottes non remaniées
Sédiments du plateau
continental
Sédiments profonds
Sédiments abyssaux

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ABSTRACT

A description is given of a new multiple corer, based on the principle of the Craib (1965) corer, which takes short samples of shelf, bathyal and abyssal sediments with virtually no disturbance. An array of plastic core tubes is lowered slowly into the sediment by a hydraulic damper mounted on a supporting framework. Experience has shown the corer to be reliable and capable of taking cores with clear, overlying water with no disturbance of the sediment/water interface.

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RÉSUMÉ

Un carottier pour le prélèvement d'échantillons multiples de sédiments non remaniés dans les domaines profond et abyssal et sur le plateau continental

Ce carottier est destiné au prélèvement d'échantillons multiples de sédiments non remaniés, soit sur le plateau continental, soit dans le domaine profond ou abyssal.

Ce carottier utilise le principe du carottier Craib (1965). Il permet le prélèvement d'échantillons superficiels non remaniés.

Une batterie de tubes plastiques pénètre lentement dans le sédiment grâce à un amortisseur hydraulique.

L'expérience a montré la fiabilité du fonctionnement et la possibilité d'obtenir des carottes ne présentant pas de perturbation sur l'interface eau-sédiment.

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INTRODUCTION

Reliable samples are essential for accurate measurements of population densities, standing crops and energy flow. When sampling benthic meiofauna, it is necessary to sample the surface layer of the sea bed without disturbing or wafting it aside first before the sampler hits the bottom. It is well-known that most benthic samplers have serious deficiencies, yet the results obtained with them are frequently subjected to sophisticated techniques of statistical analysis. The problems of "bow-wave" effects when sampling the benthos have been emphasised by various authors for macrobenthos (e.g. Ekman, 1933; Lindroth, 1935; Smith, McIntyre, 1954; Wigley, 1967; Menzies, Rowe, 1968; Flannagan, 1970; Hessler, 1971; McIntyre, 1971 b; Hessler, Jumars, 1974), for meiobenthos (Kajak,

1963; Hakala, 1971; McIntyre, 1971 b, c; Wells, 1971; Elmgren, 1973; Meischner, Rumohr, 1974; Holopainen, Sarvala, 1975; Ceccherelli, Fabbri, 1978), and for sedimentation rate and pollution studies (Baxter *et al.*, 1981).

Except for coring by divers (e.g. McIntyre, 1971 b), the authors know of only one design of core sampler capable of taking a virtually undisturbed surface sediment sample; the Craib (1965) corer slowly lowers a plastic sampling tube into the sediment under the control of a hydraulic damper. Although this corer is very successful when used in sheltered inshore waters, the authors have experienced considerable difficulties in obtaining samples from continental shelf and deep-sea sediments because valve-closing mechanisms are adversely affected by open sea conditions. Other alternatives for meiofauna sampling include the use of benthic macrofauna

samplers (e.g. van Veen grabs, Reinek box corers) and subsequent subsampling by hand with small core tubes when the large sample has been recovered on deck (e.g. Hessler, 1971; McIntyre, 1971 a; Thiel, 1971; Elmgren, 1973; Coull *et al.*, 1977; Dinet, Vivier, 1977; Dinet, 1979). However, Elmgren (1973) showed that subsampling the van Veen grab will not give truly quantitative results; only subsampling in a box corer may be considered a quantitative method, although several subsamples must be taken so as to represent the whole area within the box because the sediment surface is somewhat disturbed. Box corers seldom produce a sample with an undisturbed surface layer (Dinet, pers. comm.) and it is unlikely that, when subsampled, the distribution of the meiofauna in the surface layer of the recovered box-core sample will be the same as its distribution in the sea bed prior to sampling.

The new corer was designed to overcome these various problems and to obtain core samples, as undisturbed as possible, from sediments ranging from the continental shelf to abyssal depths. It uses the principle of the hydraulic damper in Craib's (1965) corer, but is much larger, heavier and, with present designs, can take up to 12 core samples simultaneously. This is a big advantage over corers taking a single sample when used for deep sea sampling when many hours may be spent in lowering and hauling the gear. The new design provides more samples for the time spent in taking each haul.

OPERATING PRINCIPLE

The multiple corer consists basically of four units (Fig. 1 a); a supporting framework (A), a hydraulic damper (B1 and B2) supporting a sliding framework (C) which carries an assembly of core sampling tubes (E1). Each tube takes a core sample of 56.5 mm diame-

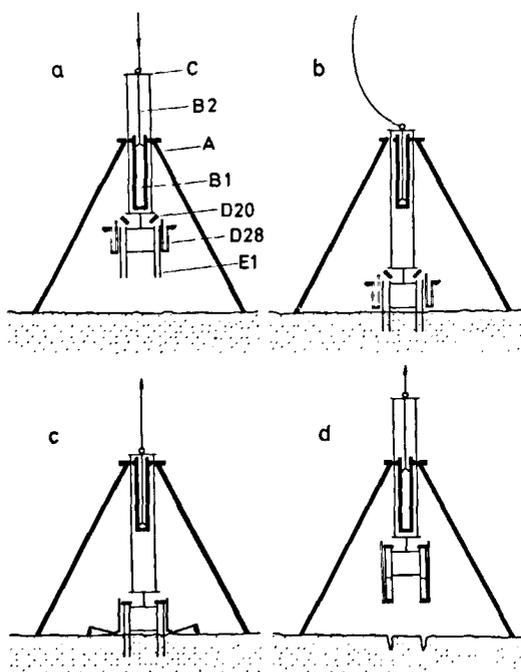


Figure 1
Schematic diagrams showing the operation of the multiple corer on the seabed. See text for explanation.

tre (25.07 cm² surface area) to a depth ranging from about 4 to 34 cm depending on the compactness of the sediment and the number of weights and core tubes being used.

When the corer is lowered to the sea bed the framework (A) rests on the bottom supporting the coring assembly in its upper position through a sliding framework (C) and hydraulic damper (B1 and B2, Fig. 1 a). As the wire from the ship is slackened, the hydraulic damper gently lowers the core assembly so that the core tubes penetrate the sea bed (Fig. 1 b, only two tubes are shown). When the wire to the ship is heaved, a special mechanism (not shown in Fig. 1) first closes valves (D20) on the top of each tube and releases bottom core catchers (D28) which swing down until they rest on the sea bed (Fig. 1 c). Continued heaving then pulls the core tubes out of the bottom, the sediment cores being retained by the seal of each top valve. As the tubes are lifted out of the sediment, the bottom catchers swing into place and help retain the cores from beneath during the ascent to the surface (Fig. 1 d).

CONSTRUCTION

Supporting framework

The supporting framework (A, Fig. 1) is cone-shaped and constructed mainly from galvanised steel scaffold tubing (Fig. 2) and standard scaffold fittings. Each of the eight legs consists of two parts (A1 and A2) clam-

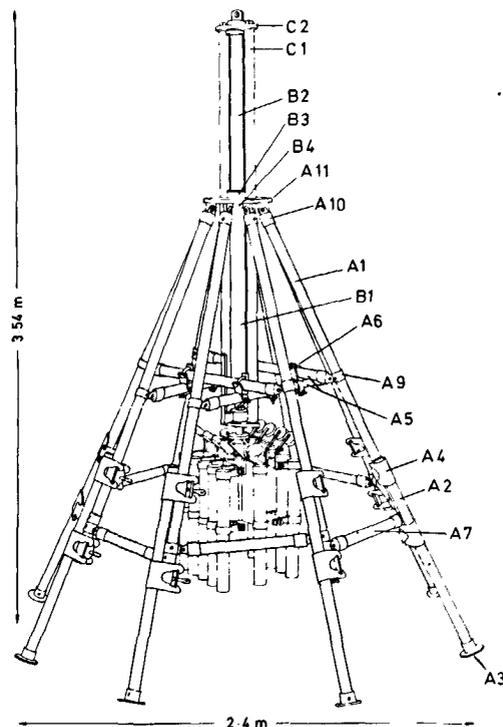


Figure 2
The multiple corer ready for lowering, loaded with twelve sampling tubes and with the top valves open. For clarity some details have been omitted; no lead weights or bottom core catchers are shown, two horizontal tubes providing an access ladder above A7 and the large-mesh plastic netting between the legs (A1) are omitted (see text).

ped together with two scaffolding universal coupling clamps (A4) to provide an adjustable total length of about 2.48 m. A2 is fitted with a small circular foot A3 (Kee-Klamp Ltd., Reading, UK). Removal of the eight lower extension legs and the core assembly reduces the corer height, width and weight to facilitate easier transportation.

The framework's cone shape is maintained by two pairs of upper tubes (A5) connecting pairs of opposite legs and rigidly joined, at right angles, by four double coupler scaffolding clamps (A6). Eight lower tubes (A7) are fitted between adjacent legs around the horizontal circumference of the framework. This arrangement allows a small amount of lateral flexibility in the lower part of the frame so that if the frame swings against the ship during deployment or recovery in rough weather, some of the impact is absorbed, lessening disturbance to the core samples by shaking. Additional lengths of tube (not shown in Fig. 2) between two adjacent legs provide a convenient ladder for access to the top of the corer when shackling on the ship's wire. All these various cross-tubes are connected to the legs by hinged scaffolding couplers (A9) (Kee-Klamp Ltd., Reading, UK). The use of scaffold tubing and various designs of scaffolding couplers permits rapid replacement of any damaged legs or struts.

The top of each leg is fitted with half a hinged scaffold clamp (A10) which is bolted to one of eight radiating vertical lugs welded to the underside of the horizontal circular head plate (A11).

Hydraulic damper and sliding framework

The hydraulic damper cylinder is a stainless steel tube (B1, Fig. 2, 3 and 4) fitting a hole in the centre of A11 (Fig. 2 and 4) and held there by two threaded collars (B3 and B4, Fig. 4). The bottom of the cylinder is closed by a threaded stainless steel end cap fitted with a rubber O-ring seal and is rigidly fixed to the supporting framework by a special bracket (B5, B6 and B7, Fig. 3 and 4) clamping two of the framework cross-tubes (A5, Fig. 2 and 3).

The sliding framework (C, Fig. 1) has two long parallel galvanised steel tubes (C1, Fig. 2, 3 and 4) joined top and bottom by two galvanised elliptical plates (C2, Fig. 2 and 4 and C3, Fig. 3 and 4). A small hole drilled near the top of each tube prevents these otherwise closed tubes from collapsing under pressure when used at great depth. The two tubes slide in the head plate (A11), on opposite sides of the hydraulic damper, and through the two short tubes (B6, Fig. 3 and 4) in the lower supporting bracket. C4 (Fig. 4) fitted through plate C2 has a dual role providing a ring for shackling to a swivel on the end of the ship's wire, whilst a galvanised tube (B2) is screwed into the underside. A leather or nylon cupwasher (B8) bolted to the lower end of this tube closely fits the bore of cylinder B1, and provides the piston for the hydraulic damper.

C5 on plate C3 provides the mounting for the core assembly, whilst two brackets (C6, Fig. 3) may be loaded with lead weights (*see later*).

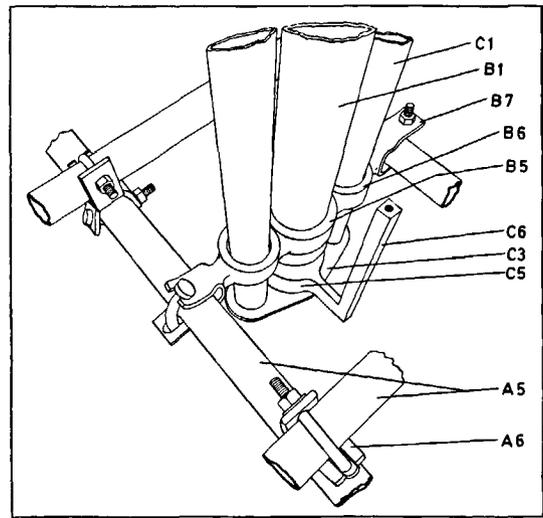


Figure 3
Details of lower end of hydraulic damper (B1) and its support bracket (B5, B6 and B7), with the lower end of the sliding framework (C1 and C3) in a raised position and showing one of the two holders (C6) for the additional lead weights (Fig. 9b). The core assembly bolted beneath C3 and C5 is not shown.

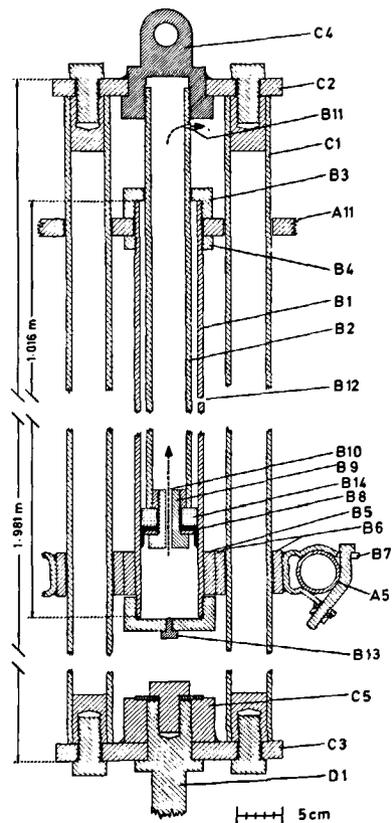


Figure 4
Section showing construction of the sliding framework and hydraulic damper and the method of venting.

With the supporting framework resting on the seabed, the sliding framework and attached core assembly descend to the seabed and their weight, supported by the cupwasher, forces water in the hydraulic cylinder up through a small hole (B10, Fig. 4) drilled down the axis of the bolt (B9) holding the cupwasher in place, and is vented through hole B11. The more obvious method of venting through a hole in the endcap at the

bottom of the hydraulic damper cylinder would direct a jet of venting water on to the surface of the sediment during sampling. The design also avoids emptying of the cylinder after the corer is recovered on deck when the water draining on to the core assembly would be a nuisance while attending to the samples.

A small hole (B12, Fig. 4) in the side of the hydraulic cylinder, near the top, is immediately beneath the level of the cupwasher when the latter is fully raised. This permits water to fill the empty hydraulic cylinder during the initial lowering, whilst the air being displaced flows out through the vent hole (B11). When the corer frame is resting on the bottom, hole B12 becomes ineffective as soon as the cupwasher slides past it at the start of its descent. When sampling has finished, the cylinder may be drained and flushed with freshwater by removing a screwed plug (B13) in the centre of the lower end cap. If the initial sampling is in shallow water the corer should first be suspended in the sea for a few minutes to allow the empty hydraulic damper cylinder to fill with water, otherwise air being vented during sampling will result in too rapid a descent of the core tubes into the sediment.

Coring assembly

The coring assembly, with the exception of some plastic and rubber components, is made entirely of stainless steel and is bolted to the bottom plate (C3) and collar C5 (Fig. 4) of the sliding frame by a single bolt. It consists of a central column (D1, D2, Fig. 5, 6 and 7) with either two or four removable radiating frames (D11, Fig. 5 and 7) to which the coring tubes are attached. Two opposite frames each carry only one sampling tube (6 and 12, Fig. 5). The other two opposite frames can each carry from one (3 and 9, Fig. 5) to five tubes. The maximum of 12 tubes consists of two rows of five (1 to 5 and 7 to 11) plus the two additional tubes, 6 and 12, mounted on their own frames. This particular pattern evolved because originally the corer was used with only four tubes, Nos. 3, 6, 9 and 12; cores 1, 2, 4, 5, 7, 8, 10 and 11 were added at a later date to provide additional material.

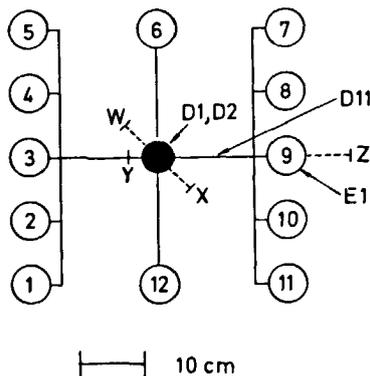


Figure 5
Plan to show the arrangement of core tubes. W-X refers to the section shown in Figure 6 and Y-Z to the side views shown in Figure 7a and b.

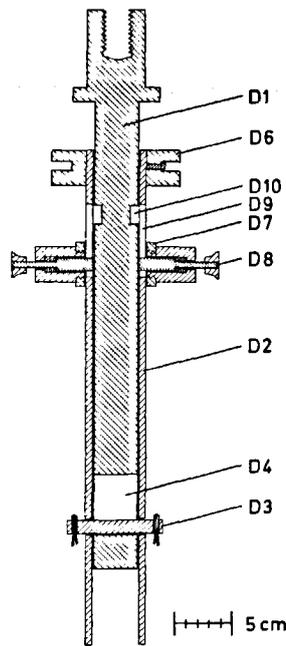


Figure 6
Vertical section of the central column of the core assembly (W-X, Fig. 5).

Experience has shown that variable numbers of coring tubes may be used in virtually any combination although it is probably best to fit tubes as a reasonably balanced arrangement around the central column (D1, D2).

The central column (D1, Fig. 6) slides in tube D2, movement being limited by pin D3 which is retained in two holes in the wall of tube D2 but can move up or down within the slot D4 in rod D1. This movement provides the basis for the mechanism that releases the core tube valves immediately before the tubes are extracted from the sediment. These valves are held open by four sliding clips (D5) (only three shown in Fig. 7a, b) mounted in a grooved collar (D6, Fig. 6 and 7) on D2 (Fig. 6). A loose collar (D7) can slide up and down tube D2 between D6 and the tops of the radiating frames (D11, Fig. 7a, b) supporting the core tubes. This collar has two spring-loaded pins (D8, Fig. 6) on opposite sides which press against column D1 by passing through two slots D9 machined through the walls of D2. In one position these pins will drop into groove D10, machined around column D1. When the corer is set for sampling, the two spring-loaded pins D8 are withdrawn from groove D10 so that collar D7 can be pushed down tube D2 to the top of the frames D11 (Fig. 7a). As the core tubes penetrate the bottom, the core assembly weight is increasingly supported by the sediment so that column D1 slides down within tube D2 until the top of slot D4 rests on pin D3 (Fig. 6). By this time, groove D10 has moved into collar D7 so that the two spring-loaded pins D8 slip into the groove. The central column then continues to force the core tubes into the sediment down to the limit of the hydraulic damper, or until friction prevents further penetration of the sediment. When the ship's wire is heaved, column D1 is lifted and collar D7, now locked to D1 by the two spring-loaded pins D8, slides up tube D2 until it lifts the four sliding clips (Fig. 7a, b), releasing the core tube valves (Fig. 7b). By this time, column D1

has been raised so that pin D3 is at the bottom of slot D4 (Fig. 6). Continued hauling then lifts tube D2 and its attached core tubes and samples, with the top valves closed, out of the sediment.

Each of the four radiating frames D11 (Fig. 7a, b) supporting the core tubes is bolted to two pairs of lugs D12 welded to tube D2 of the central column. The outer end of each frame carries one core tube on its radius and, for simplicity, only this and its associated valves will be described at this stage without regard for any additional cores attached on either side.

The plastic core tube (E1, Fig. 5 and 7a) fits through two steel rings (D13 and D14, Fig. 7a) welded to the outer edge of frame D11. It is held in place by a special ring clip (D15 and D16) slipped over the core tube from below and pushed up to a plastic collar (E2), glued and screwed to the core tube, so that the two spring clips D16 locate on two small projecting studs (D17) on the outside of lower ring D14.

The top valve (D20, Fig. 7a) is mounted on a steel arm (D19), hinged to the top of a short pillar (D18) on the top of frame D11. A strip of steel (D21), bolted to the top of valve arm D19, is held in the sliding clip D5 to keep the top valve open. The valve consists of a disc of thick uPVC plastic (D20) attached to arm D19 via a small ball joint that allows the valve to rest evenly on the upper edge of the core tube when closed. A seal is provided by a disc of smooth rubber sheet glued to the underside of D20. The rubber surface and the top of the plastic core tube must be completely flat and smooth otherwise the top valve will leak. Pressure is applied to each top valve by long rubber loops (D42,

Fig. 7b) stretching from the bottom of frame D11 over the top valve arm (D19). These should exert a pressure of about 8 kgf on each top valve to ensure the valves remain firmly in position whilst the corer is being hauled to the surface, particularly in rough seas.

The bottom catcher mechanism slides in a square-section elongated box (D22) bolted to the outer sides of the two rings D13 and D14 (Fig. 7a, b). The upper part is a spring-loaded rod (D25) with an adjusting nut on the top to vary the spring tension and screwed into a small square section steel block (D26) that slides in the elongated box D22. A short steel link (D27) provides a double hinge joining D26 to the lower half of the catcher arm which is of square-section uPVC plastic (D28). The lower end of arm D28 carries, at right angles, a short arm (D29) on which the bottom core catcher (D31) is mounted. The position of D29 on D28 can be adjusted by loosening a locking bolt (D30, Fig. 7b inset) and sliding D29 up or down. A small bolt through the end of arm D28 prevents the loss of the core catcher in the event of D30 working loose. The core catcher is a uPVC hemisphere bolted to arm D29 and fitted with a rubber cover. The complete catcher and its sliding mechanism is easily removed from the core assembly by unscrewing the nut on the top of rod D25, and sliding it out of the box housing D22. When fitted, rod D25 passes through a round hole in the small end-plate D23 (Fig. 7a) whilst the upper part of arm D28 slides in the square-sectioned housing D22 so that it cannot rotate but holds the bottom catcher along the core tube centre-line (Fig. 7b) when the catcher is closing. To set the lower valve open,

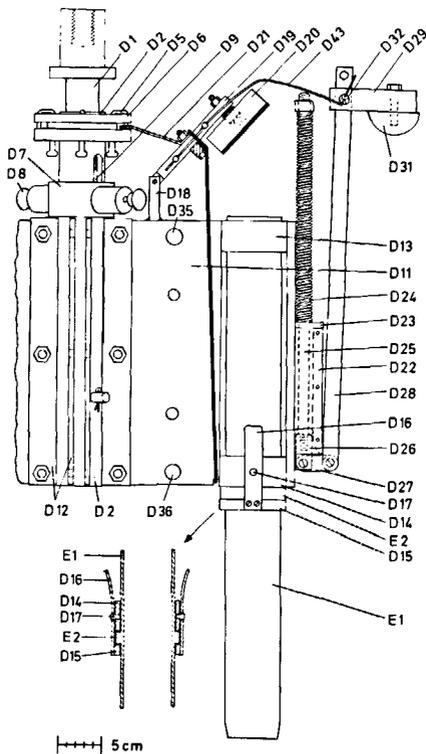


Figure 7a
Side view, along the line Y-Z (Fig. 5), of the central column, one support frame (D11) and one core tube (E1) showing the top valve and bottom core catcher set in their open positions. The inset diagram shows sectional details of the core tube and retaining clip, at right angles to the main figure.

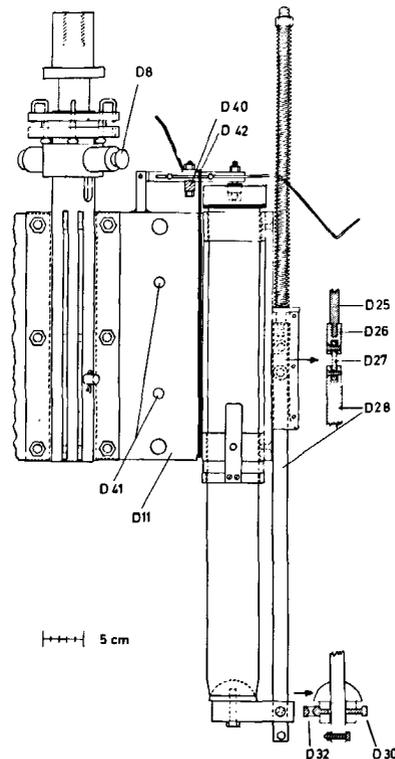


Figure 7b
As Figure 7a, but with top valve and bottom core catcher closed. The inset diagrams show sectional details of the bottom catcher, at right angles to the main figure.

the top valve must first be set in the open position. Rod D25 is then pushed down against its spring until the double-jointed link D28 is completely exposed below its housing D22 (Fig. 7a). Arm D28 may then be swung upwards away from the core tube, through 180°, so that it lies against the outside of its housing D22 (Fig. 7a), where it is held by clipping the wire hook D43 into the hole of steel catch D32 (Fig. 7a, see also Fig. 7b inset). In this position, spring D24 should exert a pressure of about 5 to 6 kgf. When the top valve is released on the sea bed, hook D43 (Fig. 7a) falls and releases the bottom valve which then swings down through about 90°, or more, until it comes to rest on the sea bed. As the core tubes are lifted out of the sediment the arm swings through another 90°, or less, and as it comes into line with rod D25, spring D24 pushes against the nut on the top of rod D25 so that the double jointed link D27 and arm D28 are pulled up into their housing D22. By this time the bottom valve is below the bottom of the core tube, against which it is pulled by the action of spring D24.

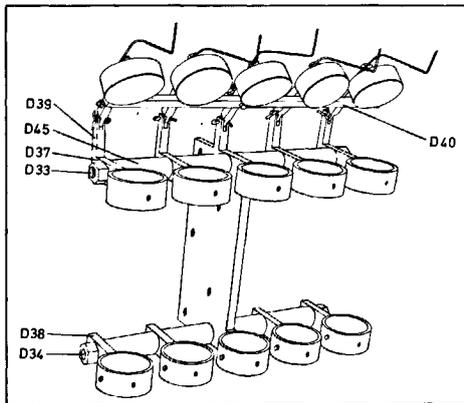


Figure 8
Details of the method of attaching additional core holders and top valves to the core assembly. Bottom core catchers are not shown.

Additional rings, to hold cores numbered 1, 2, 4, 5, 7, 8, 10 and 11 (Fig. 5) are bolted to the sides of two opposite frames. D11 (Fig. 7a, b) is one such frame, to which cores 7, 8, 10 and 11 (Fig. 5) are attached. Two steel rods (D33 and D34, Fig. 8), threaded at each end, are fitted through holes D35 and D36 (Fig. 7a) in the top and bottom of frame D11. Short lugs (D37 and D38, Fig. 8) on each additional ring are fitted onto D33 and D34 with pieces of tube as spacers (D45), to keep the core tubes separated by uniform distances (100 mm from centre to centre). Lugs on the top rings (D39) provide the mountings for the additional top valves. The slide housing (D22, Fig. 7a) for each additional bottom catcher is bolted to the upper and lower rings in a similar manner to that shown in Figure 7a, b. Tightening the nuts on the ends of each rod (D33 and D34, Fig. 8) then clamps the additional rings firmly in position.

The top valves of the additional cores are held open by a steel bar (D40, Fig. 8) bolted to the underside of the middle top valve arm (D19, Fig. 7a) mounted on frame D11 which lifts the four additional top valves (Fig. 8). When the top valve (D20, Fig. 7a) is released

from clip D5, bar D40 (Fig. 8) also falls, allowing the additional valves to drop into place on top of each core tube. In this position, it is important to ensure that there is a small gap between the top of bar D40 and the underside of each additional top valve arm, otherwise these valves may not seal properly. Rubber loops to close the additional top valves are fitted in the manner already described. The additional bottom core catchers operate as described earlier.

The 610 mm long × 63 mm o.d. × 3 mm wall thickness plastic core tubes (E1, Fig. 7a) may be made from either clear uPVC or Perspex tubing. Originally Perspex tubing was used successfully but has now been replaced by cheaper Simona PVC-Glas clear pipe. This is much less brittle than Perspex and does not crack or break readily if dropped on deck. Although manufactured with a nominal 3 mm wall thickness, each piece of tubing used by the authors varied from 3 to 3.5 mm, providing an internal diameter of 56.5 mm and a surface area of 25.07 cm². Plastic tubes often show considerable variations in wall thickness and diameter and these should be carefully checked. The wall at the lower end of each tube is tapered in to the inner surface to provide a cutting edge. The upper end is machined flat on a lathe and then ground on a flat steel or glass surface by hand, with fine carborundum paste, to provide a good seal with the top valve. Before use, the top of each tube should be carefully inspected for flaws or scratches and, if necessary, ground smooth again. The plastic collar is cemented and screwed firmly in place on the core tube so that when the tube is pushed into the supporting rings from beneath until the collar is against the lower ring, the top of the tube should project above the upper ring by several mm. Failure to project means that the top valve will not seal properly since it will rest on the top of the upper ring instead of the tube.

Twelve 8 kg lead weights (Fig. 9a), to increase sediment penetration by the core tubes, are bolted to the frames (D11, Fig. 7b) through holes D41, three weights being fitted on each side of two opposite frames. These

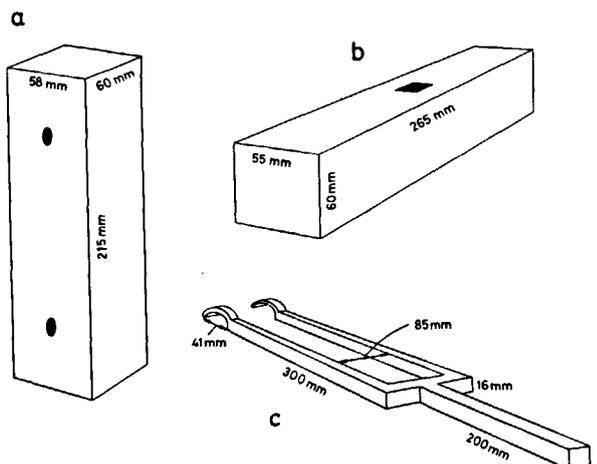


Figure 9
a) Lead weights for attaching to the core assembly; b) lead weights for the sliding framework (C6, Fig. 3); c) tool for resetting a row of five top valves (Fig. 8).

are usually adequate for penetration of most sediments by four core tubes. When twelve tubes are fitted, ten additional 10 kg lead weights (Fig. 9b) are placed on the two special fittings (C6, Fig. 3) on the bottom of the sliding framework. A bolt and washer screwed into the top of C6 prevents loss of weights if the corer should fall on its side.

Triangular shaped pieces of coarse-meshed horticultural plastic netting are tied to the frame to fill the gaps between the eight legs down to the tops of the lower extension legs. With the corer on the seabed this prevents the bight of the slack wire from the ship falling into the spaces between the legs and fouling the core assembly.

OPERATING TECHNIQUE

On board ship, when fitting the extension legs to the corer, their position should be adjusted so that with the hydraulic damper at the lower limit of its travel, the multiple core assembly, without any core tubes fitted, will just rest on the deck. This means that, assuming the feet do not sink into the sediment, full penetration of the core tubes will result in each tube being about half full of sediment. Thus, the maximum core length is about 30 cm; longer cores indicate that the corer feet have sunk into the sediment. Shorter cores show that plastic tubes have failed to penetrate fully due to the compactness of the sediment or to some obstruction in the sediment such as stones or pebbles. If only one large obstruction (*e.g.* a rock) is encountered by a single core tube on the sediment surface this results in all core tubes failing to penetrate the sediment.

Using all the lead weights on the sliding framework (Fig. 9b and C6, Fig. 3) raises the centre of gravity of the corer, which may fall on its side more easily if used on a sloping bottom or it can turn on its side if the corer is lowered too rapidly through the water column ($>90 \text{ min}^{-1}$).

The multiple corer has only been used aboard the UK research vessel R.R.S. Challenger where it is deployed on a 13 mm wire from a large "A"-frame mounted on the stern. The authors have not used the corer from the ship's side but this should be possible using a suitable boom or "A"-frame. One problem would be preventing the corer from swinging against the ship's side when the vessel is rolling. Whilst the corer frame is designed to absorb some of the impact, this should be avoided otherwise the sediment samples may be shaken and disturbed; use of the corer over the stern lessens this possibility although in heavy swell impacts can occur if the ship is pitching steeply.

Experience has shown that swell conditions are generally more critical than wind strength at the time the corer is being deployed. For example, on one occasion the corer was used successfully in Force 8-9 winds in the open ocean before a heavy swell had time to develop. On the other hand, there have been occasions when it was impossible to use the corer in Force 4 to

5 winds because the swell was too high as a result of much stronger winds a few hours earlier. During prolonged periods of strong winds the corer has been used in the swell conditions accompanying up to Force 6-7 winds in the open ocean.

It is very important to use a good, reliable swivel between the corer head and the ship's wire to allow for twists as the wire is payed out and as tension is eased when the corer settles on the seabed, otherwise "catspaws" can develop in the wire where breaks may occur as the corer is heaved off the bottom.

To monitor the corer's position relative to the sea-bed, particularly when lowering in deep water, a 10 kHz acoustic pinger (Institute of Oceanographic Sciences, Wormley, Surrey, UK) is clamped to the wire about 50 m above the corer. With the pinger's transducer pointing down, a suitable precision depth recorder on the ship will record both the direct signal and that reflected from the bottom (Hessler, Jumars, 1974), thus showing when the corer reaches the bottom. Alternatively, if the ship's winching system is fitted with a load cell to measure wire tension, a recorder can be used to monitor the corer's arrival on the sea bed. This method has been used down to depths of 5 000 m in reasonably calm conditions.

Lowering speed can be as high as 90 m min^{-1} but the corer should be placed on the bottom at a speed no greater than about 40 m min^{-1} . An extra 5 to 10 m of wire should then be payed out, before stopping the winch, to allow for the ship surging and for the core assembly to descend.

As the supporting framework settles on the bottom, the foot on each leg produces a cloud of suspended sediment. Photographs taken with a camera mounted on the corer frame show that although this suspension can drift over the sampling area, the core tubes' slow descent, controlled by the hydraulic damper, is fast enough to penetrate the sediment surface before this becomes contaminated. Since the valves are not released until hauling commences, the top valves remain open for a brief period following sediment penetration, which might permit some organisms to escape; however, the 30 cm or more length of tube above the sediment reduces this possibility.

The corer should be left on the bottom for at least 1.5 to 2 min. to allow for maximum penetration of the sample tubes. It is then heaved off the bottom with a wire speed of about 40 m min^{-1} but this may have to be varied according to the sea conditions. In heavy swells, it may be necessary to haul off the bottom at up to 90 to 120 m min^{-1} to avoid the corer bumping on the bottom. The recovery speed to the surface can be as high as 120 m min^{-1} .

In rough conditions, the corer should be hoisted right up to the extended "A"-frame, to reduce the chances of it swinging against the ship's side or stern. Where the ship is being kept on station using a combination of bow-thruster and main propulsion and the corer is being deployed over the stern, it is advisable to have the propeller stopped whilst the corer is being hoisted through the final few metres of surface water. Other-

wise the water flow from the propeller will force the corer away from the ship's stern so that when it is hoisted clear of the water it may swing back and hit the stern violently.

After sampling and just before the corer is lowered to the deck, a wooden stick inserted between the tops of the sliding and supporting frameworks (C2 and A11, Fig. 2) prevents the core assembly from being lowered onto the deck as the weight is taken off the wire. With the corer resting on deck the two spring-loaded pins (D8, Fig. 7b) on sliding collar D7 are pulled out of the groove (D10, Fig. 6) by hand and the collar is reset by sliding it down tube D2 (Fig. 7a) ready for the next sampling. Rubber bungs are then pushed into the bottom of each core tube, replacing the bottom catchers, and the top valves reset. A metal tuning fork-shaped device (Fig. 9c) is a useful aid when resetting a row of five top valves; its leverage counteracts the cumulative tensions from the five rubber bands. The two prongs of the fork are fitted on either side of the top valve of the centre core tube, beneath the rod (D40, Fig. 8) so that the curved ends of the prongs rest on the top of the upper spacing tubes (D45). When the fork handle is levered upwards, all five valves are lifted and held open in clip D5 (Fig. 7a). Where only two or four core tubes are being used, the individual top valves can be set by hand. Each core tube may then be withdrawn from beneath by releasing the retaining clips (D16, Fig. 7a; inset).

OPERATIONAL EXPERIENCE

During several years of development the SMBA multiple corer has been used successfully aboard R.R.S. Challenger (Fig. 10) to sample sandy shelf sediments, mixed sediments from the continental slope and globigerina oozes from bathyal and abyssal depths, in northeast Atlantic waters ranging from the Faeroe, Malin and Irish Shelves, Rockall Trough, Porcupine Seabight and Porcupine, Iberia and Madeira Abyssal Plains (33°N to 62°N). Samples have also been taken on the tops of the Wyville-Thomson Ridge, the Rosemary and Hebridean Seamounts in the Rockall Channel and on the Josephine and Tore Seamounts north of Madeira.

In general, the globigerina oozes and fine silty sands permit the most straightforward sampling (Fig. 11). Less cohesive gravelly sands and coarser sediments tend to run out of the core tube before the bottom catchers drop into place. Exceptions have been the gravels on the Wyville-Thomson Ridge and Rosemary Seamount in the northern Rockall Trough where an underlying layer of clayey mud provides a good plug at the bottom of the core tube during extraction and recovery of the cores (Fig. 12). In some sediments, for example those of the Rockall Trough, to the west of Ireland, and the Porcupine Abyssal Plain, further south, the sediment below about 5 cm is sufficiently cohesive to form a very effective plug at the bottom of the sampling tube. This is also resistant to water turbulence during recovery, so that the corer can be used without bottom

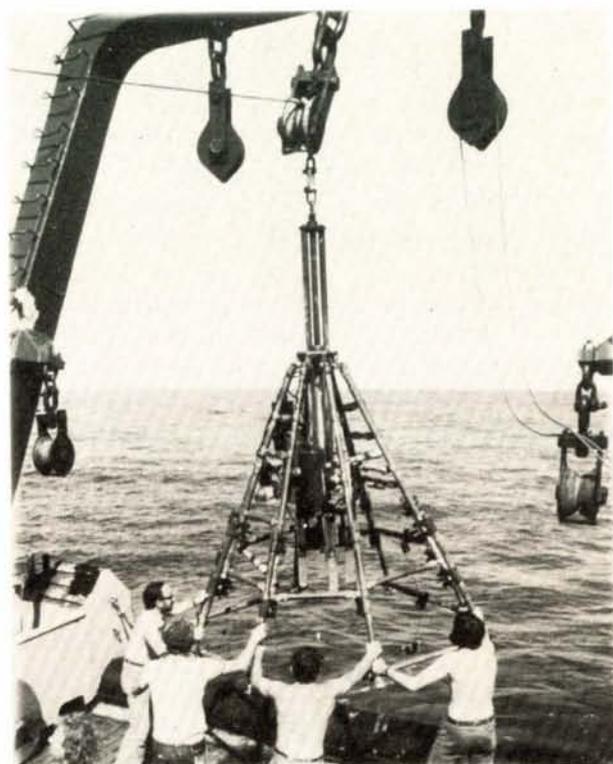


Figure 10
Multiple corer, fitted with four sampling tubes, being deployed over the stern of RRS Challenger.

valves. However, this depends on the top valves providing a perfect seal to retain the cores. Otherwise even slow top-valve leaks will result in the eventual loss of cores, particularly when hauling for an hour or more from great depths. Furthermore, as soon as the top valves emerge into the air during recovery they leak more readily. On several occasions the authors have witnessed good mud cores, hauled to the surface from 3000 m depth, slide out of their core tubes due to top valves leaking in the atmosphere. Use of the bottom

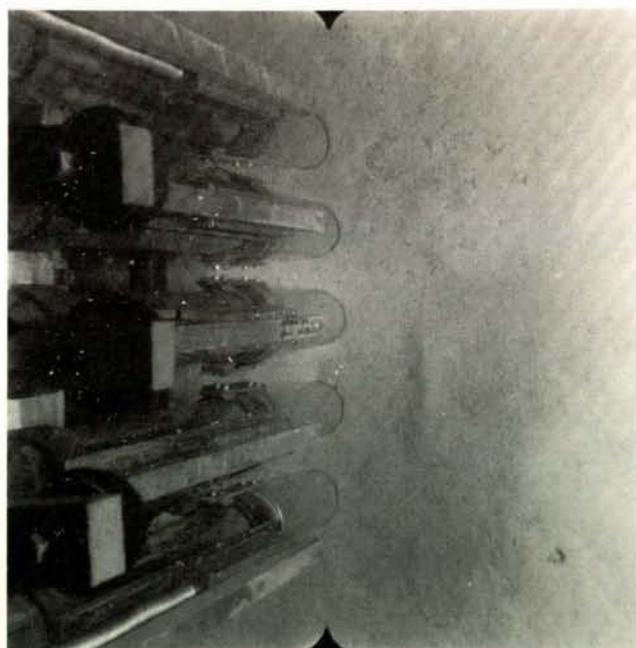


Figure 11
An array of five core tubes penetrating a globigerina ooze at 1500 m on the Hebridean Terrace (56°40'N 09°33'W), with no visible sign of disturbance.



a



c



b



d

Figure 12

Sequence of sampling with four tubes (only two are visible), at 900 m between the Wyville-Thomson and Ymir Ridges ($60^{\circ}09.6'N$ $08^{\circ}12.5'W$). Fig. 12a and 12b (14 sec. later) show core tubes descending to the sediment surface, which is a coarse gravel overlying a soft ooze. Disturbance is caused by the core tubes pushing some pebbles aside and others into the ooze layer beneath (Fig. 12c photographed 14 sec. after Fig. 12b). Ooze is forced to the sediment surface and covers some of the gravel (Fig. 12d, taken 2 min. 20 sec. after Fig. 12c). Sampling was with a prototype corer showing some design differences to the sampler described. The compass shows the orientation of the corer and the white nylon cord indicates current direction.

valves at all times is a good precaution. In other, less cohesive sediments the bottom valves are essential to prevent erosion of the core sample from beneath by water turbulence during recovery.

In general the corer has proved to be a reliable means of taking undisturbed cores of sediment. As long as the weather is suitable for the corer to be deployed at the surface it can be relied upon to take satisfactory samples. However, steeply sloping bottoms can cause problems due to the corer falling on its side. In these circumstances, use of only four core tubes and removal of the additional weights on the sliding framework can improve the chances of success. The corer works best on sands, muds and oozes and, on some cruises, has provided complete sampling success. For example, on several cruises to two routine stations at 5000 m on

the Porcupine Abyssal Plain and 3000 m in the Rockall Trough, seven drops of the corer, fitted with 12 tubes, have provided 84 core samples of globigerina ooze at each station.

To measure bottom water temperatures a reversing thermometer mounted in a reversing framework taken from a National Institute of Oceanography 1 l water bottle has been clamped in a suitable position to the coring assembly within the supporting framework. A short cord to one of the release clips holding the valves open (D5, Fig. 7a) keeps the thermometer inverted during descent but is released, to reverse the thermometer, when the corer is triggered on the bottom.

A 70 mm Shipek camera and strobe flash unit mounted within the framework has photographed, at 14 sec. intervals, the sequence of sampling events. This has

confirmed the undisturbed nature of the sampling process in sand, mud and ooze sediments (Fig. 11). This has been used to advantage to sample the seasonally deposited phytoplankton debris that forms a flocculent detrital layer on the surface of deep-sea sediments at certain times of the year (Scottish Marine Biological Association, 1982; Billett *et al.*, 1983). The corer has proved to be a successful method of sampling for studies of the microbiology (Hartwig, Stanley, 1978; Brown, Battersby, 1983) and Foraminifera (Haynes, 1981) of shelf and deep-sea sediments. A recent development has been its use in the measurement of oxygen uptake in sediment cores incubated virtually *in situ* at depths down to 5000 m (Patching, Raine, 1983).

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