NOAA Technical Memorandum NMFS-NE-224

Construction of an Inexpensive Gravity Sediment Corer for Microprofiling O^2 and pH in Marine Sediments

US DEPARTMENT OF COMMERCE
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Construction of an Inexpensive Gravity Sediment Corer for Microprofiling O^2 and pH in Marine Sediments

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ABSTRACT

A single gravity corer was constructed with a frame assembly that was used to obtain intact cores for micro-electrode measurements. Sediment cores were taken in fine sand and clay sediment without noticeable disturbance of the sediment-water interface. The sampler can collect sediment cores up to 30 cm, can be handled easily by two people, is relatively inexpensive ($US 1,200), and can be used in water depths up to 50 m.

Keywords: sediment core; sediments;

INTRODUCTION

Obtaining intact sediment cores in estuarine environments can be difficult because of variations in water depth (20-50 m) and sediment grain size (from coarse sand to very fine clay). There are two basic types of sediment corers: surface and long corers. Surface corers, such as the Hongve corer (Hongve 1972) and the Griffin corer, allow for recovery of the sediment-water interface and the sediment immediately below. Long corers, such as the Nesje corer (Nesje 1992) and the Livingstone corer (Livingstone 1955), are used to penetrate to the maximum sediment depth possible, depending upon water depth, tube length, and sediment type. Large-diameter gravity corers (7.0 cm or greater) are often used to conduct geochemical analyses of marine sediment. The advantage of a gravity corer is that it is mechanically simple, robust, reliable, and requires little maintenance. However, some disadvantages of gravity corers are that they are heavy, awkward to deploy, and the cores must be lifted vertically. Development of micro-electrodes has allowed for some geochemical analyses on smaller core diameters (5 cm). While studying the geochemical effects of dredging upon marine sediments, we constructed a gravity corer to work in sediments ranging in grain size from fine sand to clay, to have a small core diameter (5 cm), and to be used with micro-electrodes. In this paper, we describe a simple, inexpensive single gravity corer with a sediment extractor which was successfully used to measure chemical changes at the sediment water interface (Meseck et al. in prep).

COMPONENTS

The sediment coring system consists of a corer to collect sediment samples (Fig. 1) and a sediment extractor to move the sediment through the core tube. The corer consists of three separate assemblies: the frame assembly (Fig. 1); the weight assembly, which includes the polycarbonate core tube (Fig. 2); and the sediment-retainer assembly (Fig. 3). The sediment extractor was a separate piece of equipment (Fig. 4).

Corer Frame Assembly

The overall dimensions of the frame are 80 cm x 80 cm x 114 cm, with the base of the frame being slightly larger at 101 cm x 101 cm (Fig. 1). The frame assembly was constructed of steel angle iron 3.8 cm x 3.8 cm x 0.6 cm welded together at all contact points. For each corner of the base (Fig. 1), pairs of 45^{o} angles were utilized to minimize impact damage if the base were to contact an object.

Two travel guides (Fig. 1) were constructed of pieces of steel plate 20.3 cm x 16.5 cm x 1.2 cm. A 20.3 cm x 5 cm Nominal Pipe Size (NPS) piece of stainless steel pipe with an inside diameter of 3.5 cm was welded to each of the above mentioned steel plates to complete the travel guides. The travel guides then were slid onto the travel rods (Fig. 1) prior to welding the travel rods to the frame.

Travel rods constructed of 3.2 cm diameter solid steel rod 113 cm long were welded to the frame. Eight small pieces of angle iron (not shown), two at the top and two at the bottom of each rod, were used for braces. Travel stops (Fig. 1) were made from 5 cm long pieces of angle iron welded to each travel rod 30.5 cm above the frame base. The travel stops allow the weight assembly with check valve installed (no core tube) to be lowered near the base of the frame without contacting the deck or ground.

The safety latch receiver (Fig. 1), 10.2 cm x 10.2 cm x 0.9 cm, was welded to the top of each travel rod. This piece extends 5 cm above the frame and has a notch 2.5 cm x 1.2 cm cut into it. Two steel safety latches (Fig. 1), 28 cm x 5.1 cm x 0.6 cm, were attached to the travel guides with 0.9 cm diameter stainless steel bolts 3.8 cm long. Stainless steel washers were used on the end of each bolt with a stainless steel nylon insert lock nut. Tightening or loosening the lock nut allowed the friction of the safety latch to be set at a comfortable level by the user.

Corer Weight Assembly

The corer weight assembly consists of stacked steel plate weights, stainless steel pipe nipple, brass check valve, copper core tube coupler, and polycarbonate core tube (Fig. 2). Each steel plate is 30.5 cm in diameter x 2.5 cm thick and weighs 14.5 kg. Five plates were welded to make the base weight (Fig. 2). Prior to welding, four 2.5 cm holes were drilled into the uppermost plate (Fig. 2). Four 2.5 cm diameter by 31 cm long galvanized threaded rods were inserted into each hole and welded (Fig. 2). The galvanized threaded rods were used to attach the top plate and additional plate weights. Galvanized nuts and flat washers were used to secure the top plate. A 7.6 cm x 5.2 cm section of stainless steel pipe was threaded on one end and welded to the bottom plate with the threaded end pointing down (Fig. 2). Two travel guide tabs 13.6 cm x 10.2 cm x 0.9 cm, (Fig. 2), each with four 0.9 cm diameter holes, were welded to the base weight 180° apart.

Four 3.2 cm diameter holes were drilled into the top plate, which allowed it to slip over the threaded rods (Fig. 2). Four lifting tabs, 5 cm x 3.8 cm x 1.2 cm, with a centered 1.2 cm diameter hole were welded to the top plate (Fig. 2). A lifting bridle, consisting of two 129.5 cm lengths of 0.8 cm galvanized chain, was attached to the four lifting tabs with shackles (Fig. 1). A shackle was attached the center link of each piece of chain and served as an attachment point for the hoisting cable (Fig. 1). Up to nine additional plates, with four 3.1 cm diameter holes, could be added between the top plate and base weight to adjust the total weight as needed. In this example, six additional weights were used for a total weight of 174 kg.

A 5 cm National Pipe Thread (NPT) brass check valve was attached to the stainless steel nipple with the direction of flow pointing toward the base weight (Fig. 2). The core tube coupler was fabricated by soldering a 15.2 cm x 5.2 cm NPS piece of copper tubing of 5 cm (inner diameter) into a 5.2 cm NPT copper adapter with male threads (Fig. 2). A 0.8 cm hole was drilled through the copper tubing 1.9 cm from the male adapter. The core tube was 48.2 cm x 5 cm (outer diameter) polycarbonate tubing (Fig. 2). The bottom, outer edge of the core tube was beveled at 45° to facilitate penetration into the sediments. A 0.6 cm hole was drilled through the polycarbonate tube so that the core tube could be fastened to the coupler with a 0.6 cm stainless steel bolt 7.6 cm long. A 0.6 cm (inner diameter) o-ring and stainless steel washer were used on both sides of the coupler to maintain a tight seal against the copper tubing. A 0.6 cm stainless steel nut was used to secure the bolt.

Once assembled, the core weight was attached to the travel guides (Fig. 1). Four 3.8 cm x 0.9 cm diameter stainless steel bolts, each with a pair of stainless steel flat washers and a stainless steel nylon insert lock nut, were used to secure each travel tab to the travel guide. A stop collar was positioned on the core tube between the sediment retainer and the bottom of the core tube (Fig. 2). Two types of stop collars have been used successfully. The first consisted of a 2.5 cm piece of polycarbonate tubing that was split lengthwise and slipped over and cemented onto the core tube as shown in Fig. 2. The installed collar increased the outside diameter of the core tube to prevent the sediment retainer from slipping off the core tube. If it is not desirable to have a permanently installed collar on the core tube, the second stop collar could be used. This consisted of two stainless steel hose clamps, each slightly larger than one half of the circumference of the core tube, screwed together and tightened around the core tube. The adjusting screws of the hose clamps were kept 180˚ apart from each other and acted as the stops to prevent the sediment retainer from slipping off the core tube.

Sediment Retainer Assembly

The sediment retainer was constructed of Polyvinyl Chloride (PVC) because it is extremely durable, easily joined by welding, cementing, or mechanically fastening, and does not corrode when exposed to salt water. The sediment retainer described in this paper was assembled by using all of the above mentioned techniques. All PVC used to construct the sediment retainer was 1.2 cm thick (Fig. 3).

All components were first assembled dry, without cement, using 0.3 cm flat-head, stainless steel, self-tapping screws. The sediment retainer was then disassembled and reassembled applying PVC cement to all joints following the cement manufacturer’s instructions. After the cement was set, excess cement was removed from around the joints. The joints then were welded where accessible. The collar consists of three pieces of PVC cemented together with a 5.3 cm hole in the center. A 0.5 cm diameter pivot hole was drilled into each side piece (Fig. 3). A 0.5 cm stainless steel, round head, self-tapping screw and stainless steel flat washer were used in each side piece.

Sediment Extractor

The sediment extractor consists of the extractor frame, the piston assembly, and the jack assembly (Fig. 4). A frame was built by welding two uprights of 99 cm x 5 cm x 5 cm x 0.3 cm angle iron to the bottom plate 10.2 cm from the back edge of the plate. A bottom plate was constructed from a piece of steel 38.1 cm x 30.5 cm x 0.6 cm. Two cross pieces were welded across the uprights 40.6 cm and 78.7 cm, respectively, above the bottom plate. A half sleeve, fabricated by splitting a 15.2 cm length of 5.3 cm inside diameter pipe lengthwise, was welded to the center of the upper cross piece (Fig. 4). The top plate measured 33 cm x 10.8 cm x 0.6 cm. A 1.8 cm diameter hole was cut into the center of the top plate. The top plate was welded on top of the uprights so that the center of the square hole would line up with the center of the bore of a core tube (Fig. 4).

A core tube stop was constructed from a 19.3 cm x 10.8 cm x 1.2 cm piece of PVC. A 5.3 cm diameter hole was bored into the center of the bottom side of the core tube stop to a depth of 0.6 cm. A second hole 4.5 cm (same diameter as the inner diameter of the core tube) was bored completely through the center of the core tube stop. The smaller diameter hole created a shoulder for the core tube to contact during the extraction process. This shoulder prevented the core tube from being pushed through during the extraction process. The center of the core tube stop was aligned over the center of the top plate and fastened to the top plate with four 0.6 cm x 3.8 cm stainless steel bolts. Stainless steel washers and a stainless steel nylon insert lock nut were used to secure each bolt.

The piston assembly consists of a rubber stopper; PVC piston; 0.9 cm diameter threaded, stainless steel push rod; rod coupler; and push rod extension (Fig. 4). The tapered rubber stopper has a diameter at the wide end that is slightly larger than the inside diameter of the core tube. The seal between the rubber stopper and the core tube was tight enough to allow no water or sediment to leak past the stopper. A piston was constructed from two circular discs with a diameter of 4.3 cm x 1.2 cm thick PVC cemented together to form the piston. A center hole was drilled to a depth of 1.9 cm into the piston. The hole was tapped to match the threads of the push rod. The push rod was constructed from a piece of stainless steel threaded rod 40.6 cm long x 0.9 cm diameter. The push rod then was screwed into the piston. A stainless steel nut was threaded over the push rod and used to lock the push rod to the piston.

The jack assembly consists a 1360 kg capacity scissor jack; 90° drill attachment with 0.9 cm chuck (referred to as the drill chuck); 0.9 cm drive speed wrench; 0.9 cm drive socket wrench extension bar; and 0.9 cm drive, deep-style wrench socket (Fig. 4). A hex nut with 1.2 cm diameter threads was welded to the center of the top plate of the scissor jack to create a seat for the piston push rod.

A chuck coupler was fabricated from a steel bar 2.5 cm x 9.3 cm bent into a “U.” The length of the steel bar should be determined by the user. The chuck coupler was connected to the jack by drilling a 1.2 cm hole in each end of the chuck coupler and welding the coupler to the jack pivot pin through the holes (Fig. 4). The supplied handle of the jack was connected to the jack and then cut so that the drill chuck could be connected (Fig. 4). The drill chuck then was connected to the coupler (Fig. 4) by drilling holes through both sides of the coupler. These holes were aligned with a hole in the drill chuck that was intended for use with a side handle supplied by the drill chuck manufacturer. A 7.1 cm x 0.9 cm diameter stainless steel bolt was passed through these holes and secured with stainless steel flat washers and nylon insert lock nut. The drive shaft of the drill chuck was hex shaped so that a 1.5 cm, deep-style wrench socket could be connected to the drive end of the drill chuck. An extension bar and speed wrench were connected to the wrench socket with the final length of this assembly determined by the user.

Operation of the Corer

The corer described above is a modification of a gravity corer with a frame assembly to take single cores for use with micro electrodes in estuarine environments. Video footage was taken of the corer in operation to ensure that minimal sediment disturbance was occurring. Below we describe the corer in action based on the video footage. As the corer is lowered by the hoisting cable, the first component of the corer system to contact the sea bed is the core frame base (Fig. 5, panel A). The sediment retainer then contacts the sea bed and rotates out of the way exposing the bottom of the core tube. As noted in the photographs, the sediment retainer was offset by 3 in (7.6 cm) from where the core tube was driven into the sediment bed. In sandy sediment, no plume was detected (panel B); the weight of the base plates pushes the core tube down into the sediments (panel C). Simultaneously, the brass check valve opens which allows water displaced by the sediment to be expelled. Once the core tube has completely penetrated the sea bed, the check valve closes and creates the necessary suction to extract the sediment sample from the sea bed. Then the sediment retainer closes as the corer is brought up (panel D). For sediments that were classified as clay, a plume developed when the base made contact with the sediment bed (panel E); however, the core tube was in the sediment before the plume reached the core tube (panel F). Core length varied (10 cm to 30 cm) depending upon sediment type. Cores from both clay and sandy sediments came up intact, with the surface water interface clear of any disturbance (Fig. 6). Figures 5 and 6 combined with the photographs, indicate that the modified gravity corer was successful in not disturbing the sediment bottom and in maintaining the sediment water interface.

A thorough description of the microelectrodes used with the corer can be found in Meseck et al. (in prep.). Briefly, for O_2 profiling, a micro-optical, 140-µm probe was used (Loligo Systems, Denmark), while for pH, a MI-414 pH electrode in a 16-gauge needle was used. Both were attached to a micro-manipulator to obtain millimeter-scale resolution for pH. Typical O_2 and pH profiles from cores that were classified as sand and as clay can be seen in Fig. 6. The profiles obtained are consistent with cores from other marine sediments (Luther et al. 1982; Valdemarsen et al. 2010). Further examples of core profiles and an explanation of the processes that are controlling these depth distributions can be found in Meseck et al. (in prep).

POSSIBLE MODIFICATIONS

The corer described here is considered to be a very flexible design. The overall dimensions and weight of the corer could be increased or decreased to accommodate the individual needs and resources available to the user. Furthermore, 2-in NPT (5-cm) male and female cam-and-groove pipe couplers are being tested as a means to quickly connect the core tube to the core weight. If the overall size and weight were to be increased, the size and relative strength of all weight-bearing components should be assessed to ensure that the entire structure can safely carry the predicted loads.

Some cost savings could be realized by using square rather than round steel plate for the weights. Rectangular weights would allow for multiple core tubes to be attached at the same time if desired. Solid stainless steel rod and angle iron could be used for the travel rods to reduce corrosion and the need for lubrication. This would add considerable cost but eliminate almost all maintenance.

MAINTENANCE

It is recommended that all components be washed with clean, fresh water after each use. If it does not interfere with the analysis being done on the sediments, the steel angle-iron frame, steel plate components, and sediment extractor should be painted with an exterior or marine-grade primer and top coat prior to use and as needed. The travel rods should be coated with pure silicone grease prior to and after each period of use. The scissor jack, right angle drill chuck, and speed bar should be washed with clean, fresh water and sprayed with a light oil or silicone after each use.

CONCLUSIONS

The modified gravity corer was successful in obtaining intact sediment cores for micro-electrode analysis in both clay and sandy sediments. The entire costs of the sediment corer and extractor was only $US 1,200 for materials, with a total weight of 276 kg. In comparison, other commercially available corers can cost between from $US 4,000-12,000, depending upon size and weight of most traditional gravity coring devices. This coring device was simple and inexpensive to construct, and it obtained sediment cores that were suitable for use with micro-electrodes.

Note: Any use of brand name equipment in this paper does not imply endorsement by the Federal Government.

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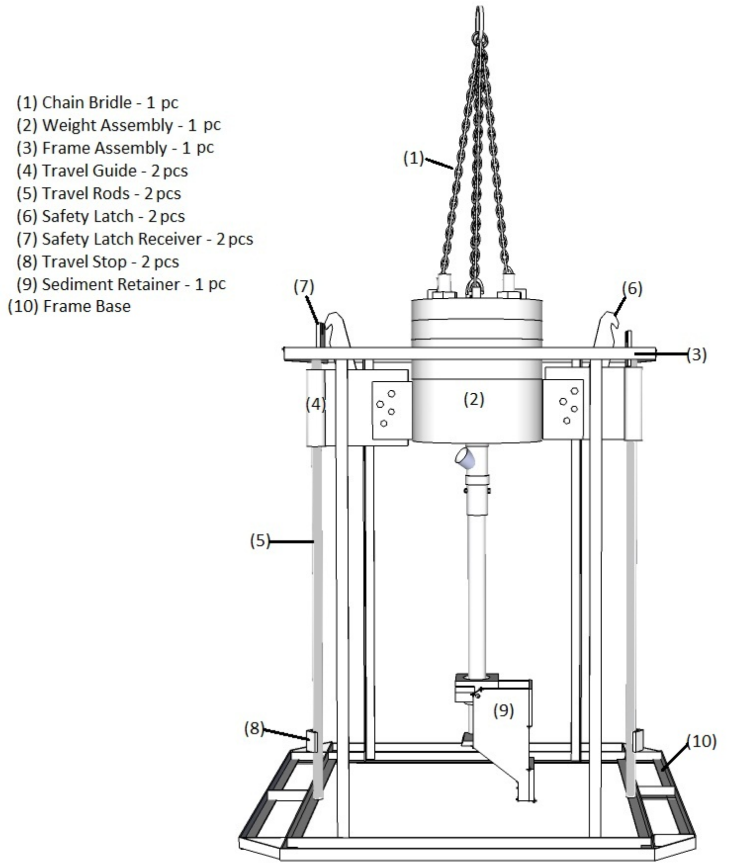

Figure 1. Diagram of the modified gravity sediment corer and frame assembly.

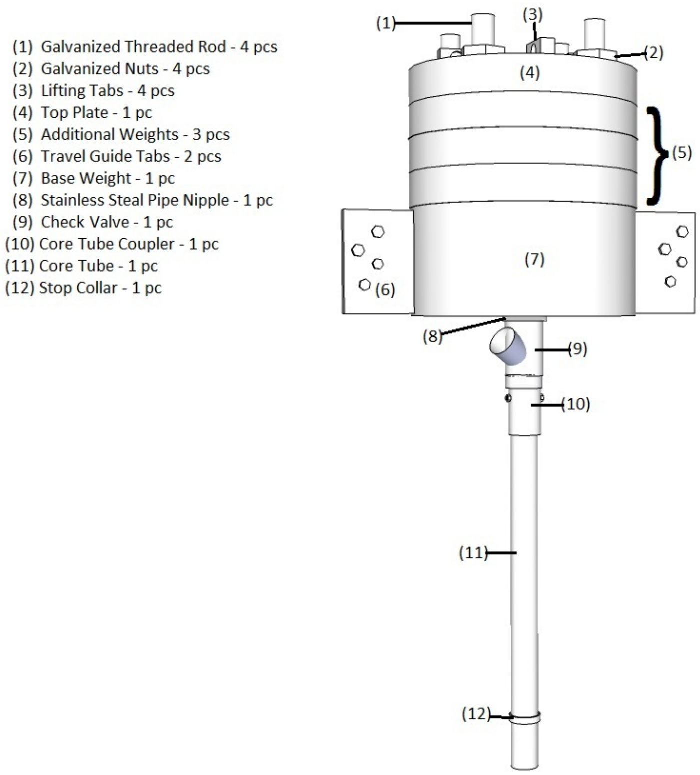

Figure 2. Diagram of the sediment corer weight assembly with a component list.

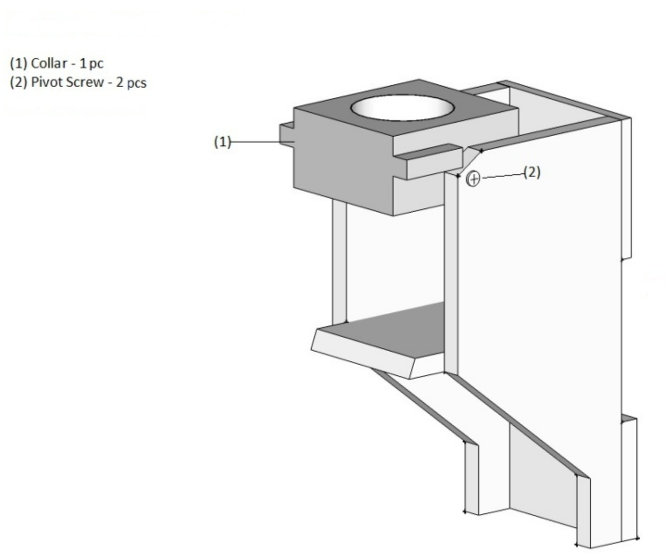

Figure 3. Diagram of the sediment retainer used to prevent sediment from slipping from the core tubes.

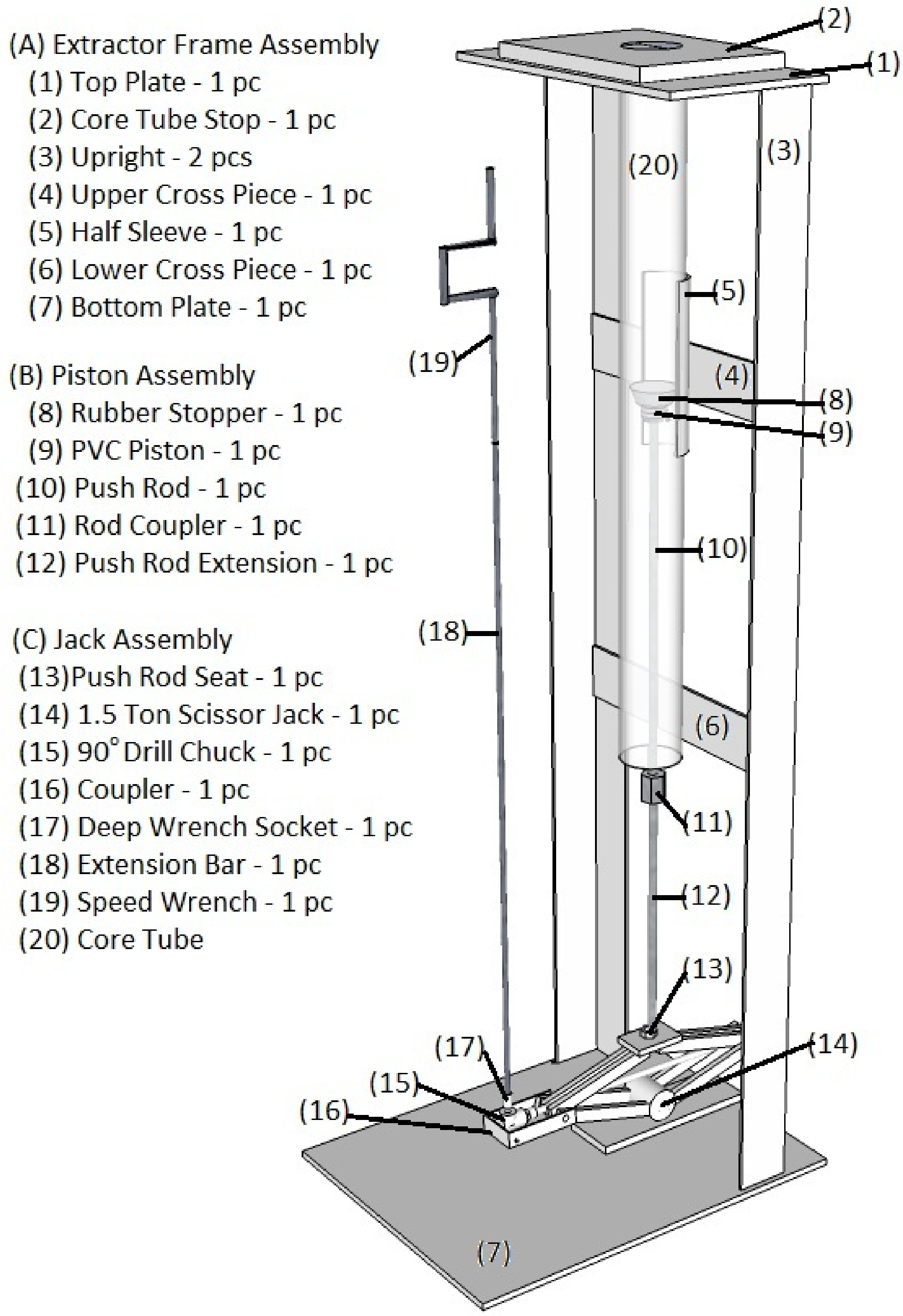

Figure 4. Diagram of the sediment extractor used to move sediment through the core tubes.

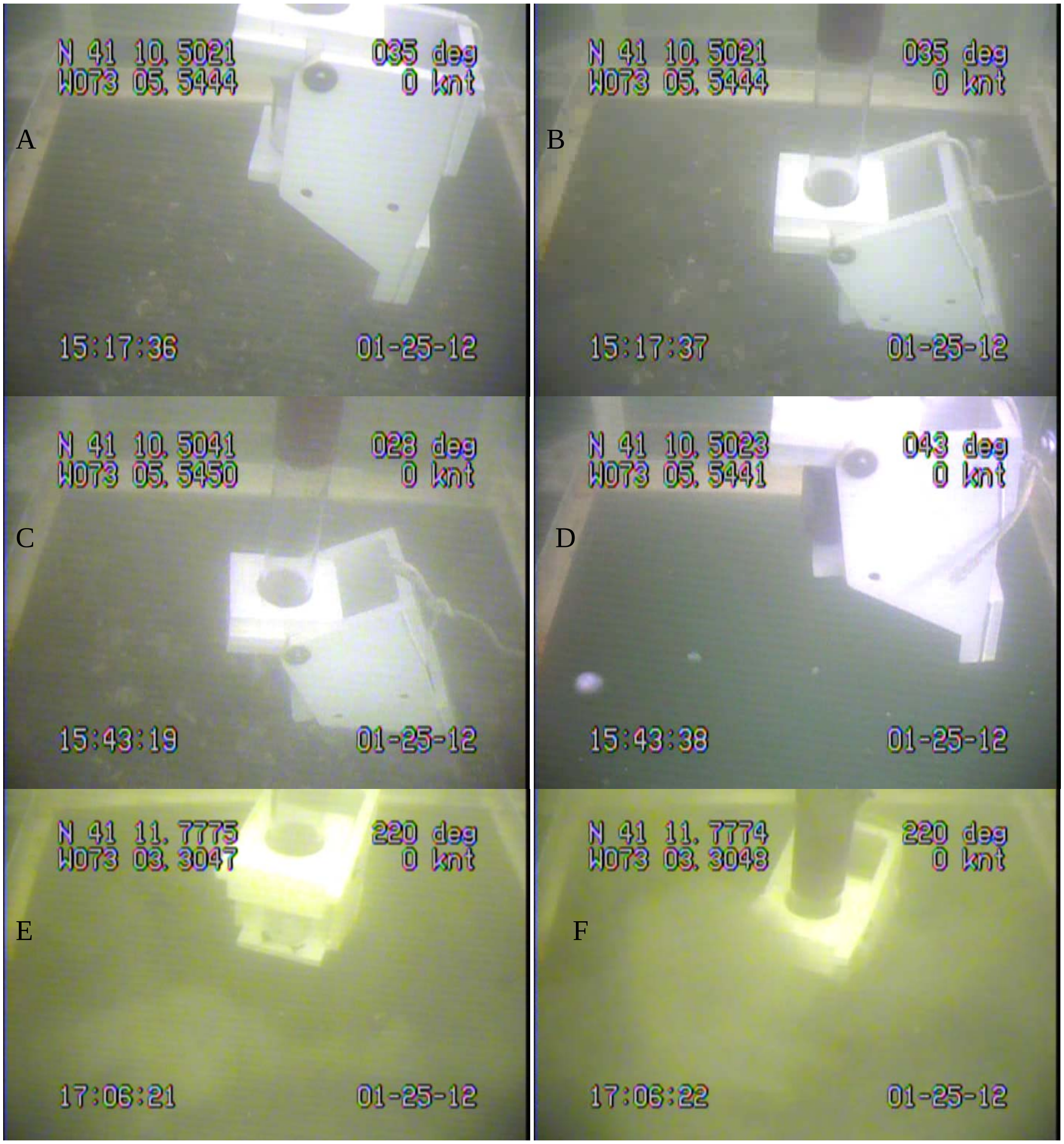

Figure 5. Still frames from video taken using the modified gravity corer. Panel A shows the corer right before touching the fine grain sandy sediments. Panel B the corer has touched the sediment, and the sediment retractor has moved out of the way of the sediment corer. As the corer is being pushed into the sediment, the retainer remains out of the way (panel C), and then it closes over the bottom of the sediment (panel D) as the sediment is being brought up. For clay bottom types, the modified gravity corer did generate a slight plume when the base touched down (panel E); however, the core tube is in the sediment before the plume has reached it (panel F).

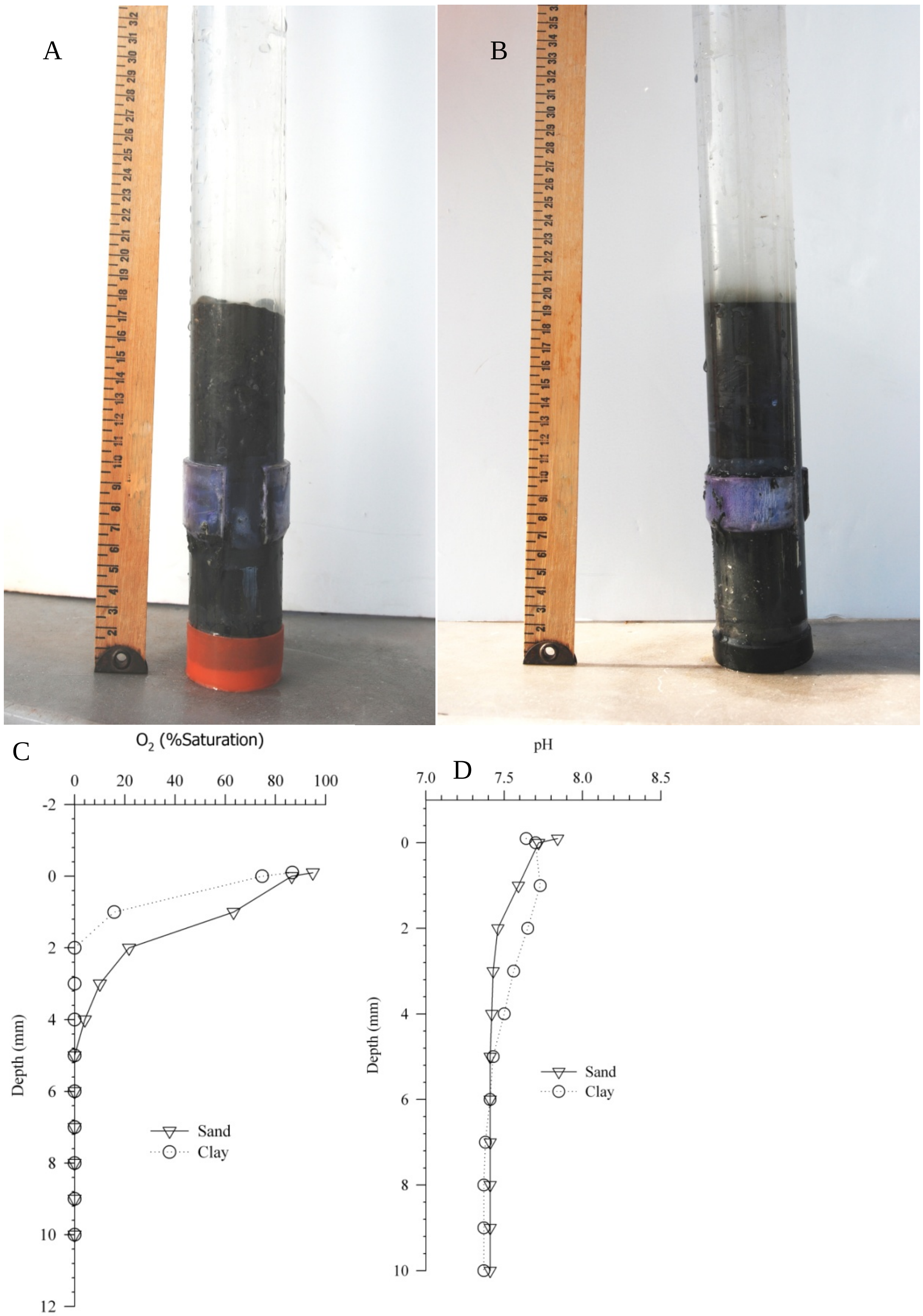

Figure 6. Sediment extracted from two different sediment types (A) sandy sediment and (B) clay sediment. As the pictures show, core lengths varied with typical corer being between 17 cm and 20 cm. The surface water interface was left intact and undisturbed for both sediment types. In panel (C) and (D) are typical oxygen and pH profiles that were obtained from cores that were collected with the coring equipment.

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