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Technical Notes and Comments

Diver-Operated Piston Corer for Nearshore Use

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ABSTRACT: A diver-operated piston corer suitable for collecting cores of >3 m length from fine-grained nearshore sediment has been developed. The corer uses a platform that rests on the sediment surface supporting both the operators and a derrick that maintains the piston at the sediment–water interface. The core is inserted into and recovered from the sediment manually. The technique offers several advantages: low cost, minimal disruption of the sediment–water interface, little compaction of the sediment, the ability to collect longer length cores than is possible with gravity corers, and the ability to be deployed from relatively small boats. Dissolved ammonium and inorganic carbon data are presented from a 3.3-m core collected by this technique from Tomales Bay, California.

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Introduction

Biogeochemical studies of estuarine sediments frequently require the collection of sediment cores that accurately reproduce vertical gradients. Freeze coring, gravity coring, and vibra-coring can be used to obtain suitable short (<1 m long) cores (e.g., Shapiro 1958; Sanders 1968; Martin and Miller 1982; Jones et al. 1992), but longer cores require piston coring techniques to overcome the effects of sediment compaction and friction during coring. Although simple hand-held pistons can be used when collecting short cores, this technique becomes difficult when core lengths exceed 1 m. Alternatively, conventional piston corers can be used, but these are complex, expensive devices that need to be deployed from at least moderate-size research vessels; these characteristics render such corers unsuitable for shallow-water applications and for deployment from small boats. For these reasons we have developed a light weight, diver-operated piston corer that features an automatically positioned piston, and that can be used with boats ≥5 m long. It is suitable for use with fine-grain sediments that do not contain sand layers more than ~3 cm thick.

Materials and Methods

CONSTRUCTION

The corer consists of a derrick with an attached base, and a core–tube–piston–pilot-line assembly (Fig. 1). The size of the platform is somewhat arbitrary, but for use on soft sediment it needs to be large enough to allow the two operators to stand on it, thereby preventing their sinking into the sediment. The platform can be hinged to ease its transportation to the field site, but will then need to have stiffening rods attached before deployment to keep it stable during coring operations. Although a variety of materials can be used to construct the platform, we have found an open-mesh structure to provide the best combination of rigidity, light weight, ease of handling in the water, and minimized disturbance of the sediment during deployment. Such a platform can be made of a framework of PVC tubing covered with a heavy plastic mesh such as ½-inch (1.2-cm) Vexar® polyethylene (available from aquaculture suppliers), and weighted at the corners with removable lead weights to make the platform negatively buoyant.

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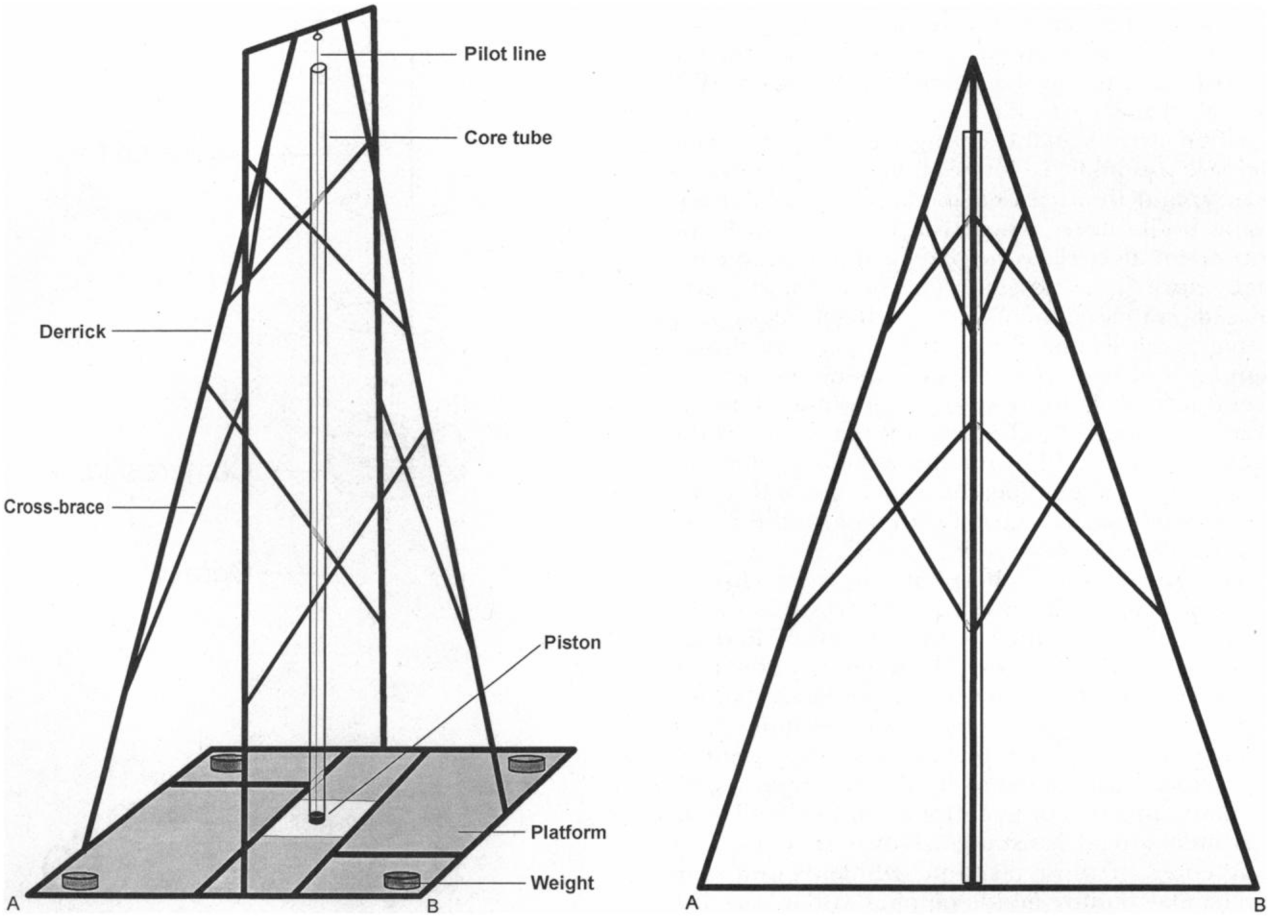

Fig. 1. Schematic diagrams of the coring apparatus used for core tubes up to 6 m long. A similar apparatus, smaller and without cross-bracing, can be used with core tubes up to 2 m long.

Derricks of up to 2 m in height can be constructed of 1-in (2.5 cm) diameter PVC tubing and T-connectors, and do not require cross-braces; such a derrick can be built and transported separately from its base, and assembled at the field immediately before deployment. Taller derricks are reinforced by placing thick-wall metal tubing (¾-in diameter electrical conduit), secured by self-tapping screws at each end, inside of the PVC tubing; additional strength is provided by 2.5-cm wide cross-braces made from "L"-section aluminum stock, which are attached by screws to adjacent upright members. We have constructed a derrick 6 m tall using this approach (Fig. 1). Holes should be drilled at the tope and bottom of each support post to allow water to flood and drain the derrick framework during deployment and recovery, respectively.

We typically use transparent core tubes made of 3-in (7.6-cm) i.d., ⅛-in (3-mm) wall polycarbonate tubing, this being a suitable trade-off between handling ease and volume of sediment recovered. Other sizes can be used, depending on the user's needs and the availability of suitably sized pistons. We have found acrylic tubes, which shatter rather easily, to only be suitable for short cores (<2 m). The outer lower edge of the tube is beveled with a belt sander to aid sediment penetration. We have successfully handled core tubes up to 6 m long.

A pilot line made of 3-mm diameter stainless steel wire is attached to the piston, and is just long enough to keep the bottom of the piston at the sediment-water interface while the core tube is driven into the sediment (Fig. 1). The piston is made from a plumber's compression test-plug; the flexible seal of the plug is compressed with the plug's wing-nut to make the contact with the core tube sufficiently tight.

Deployment

The platform–derrick assembly can be transported to the coring site by placing the platform across the transom of a boat, attaching a support line from a mast on the boat to the top of the derrick, and tilting the derrick backwards until it is ~30° from horizontal.

Upon arrival at the coring site, the platform–derrick assembly is lowered into the water, released, and then carried to the bottom by divers using bridle lines; a float can be attached to the top of the derrick to help keep the assembly upright during the descent. The platform is gently placed on the sediment at the coring location, care being taken to not disturb the uppermost flocculent layer of the sediment. The operators then descend to the platform, with one diver holding the core tube assembly. The piston is positioned at the bottom of the tube, with the attached pilot line drawn through the tube; the upper end of the pilot line is temporarily secured with tape to the upper outer wall of the core tube.

The upper end of the pilot line is attached to the clip hanging from the upper cross-bar of the derrick. The core tube is then carefully lowered onto the sediment exposed by the hole in the platform, and, while one diver steadies the tube, the other pushes the core tube into the sediment. By maintaining negative buoyancy during deployment, divers can generate enough downward force for several meters of penetration in soft mud without mechanical assistance. However, extremely long cores, or those taken in sediments with sand layers, may require gentle tapping with a lead dive weight (~2 kg) or a drop hammer (e.g., Sanders 1968; Martin and Miller 1982). The divers can use the bracing on the derrick for leverage during this process.

When the desired penetration is achieved, the pilot line is disconnected from the derrick, the piston is tightened using an extension tool (Fig. 2a), and the pilot line is coiled in the upper core tube. If the piston is too low to be reached, the pilot line is coiled in the core tube and then a separate compression plug is inserted into the top of the core tube and tightened.

Recovery

Cores of up to ~2 m length can generally be removed from the sediment by having divers twist and pull the core barrel, but longer cores need to be at least partially freed from the adhesive force of the surrounding sediment before recovery. We use a water-jet technique to remove a several centimeter thick layer of sediment immediately surrounding the core barrel. The apparatus consists of a rigid water jet constructed from 1½-in (3.8-cm) diameter PVC tubing and couplings (Fig. 2b); approximately 20 5-mm holes are drilled into the bottom of the circular portion of the assembly to

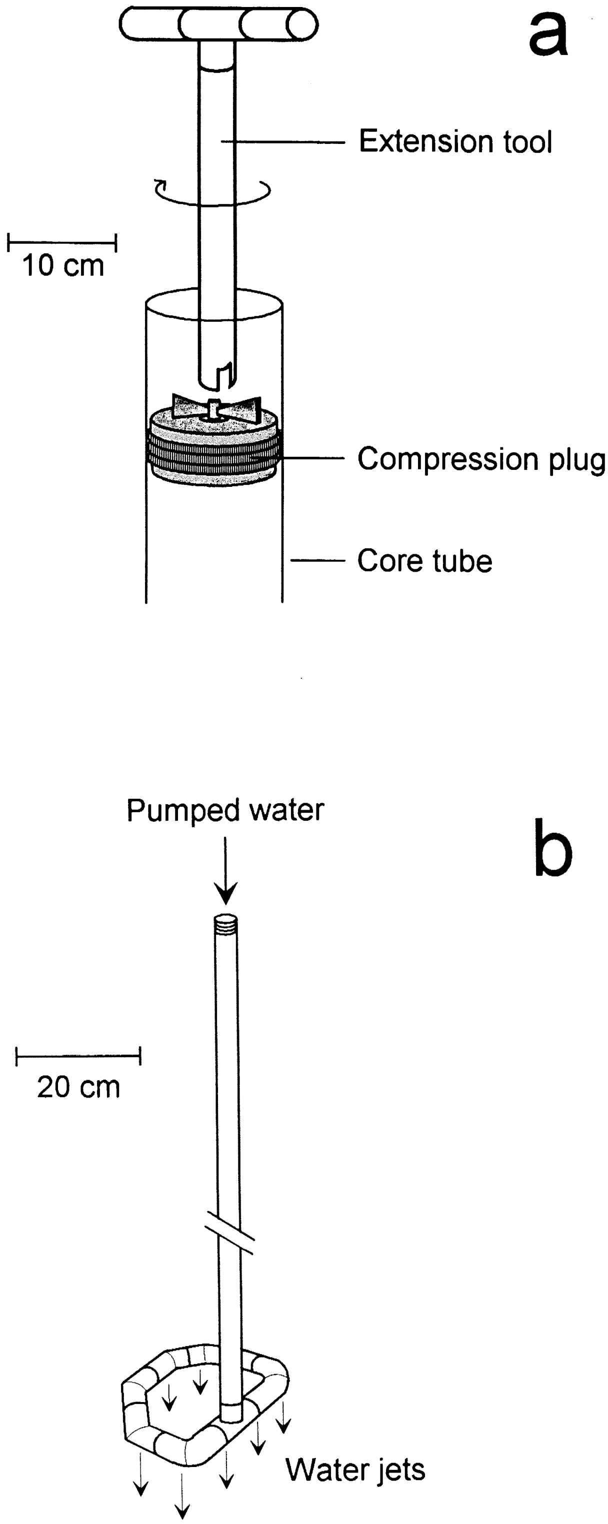

Fig. 2. Schematic diagrams of a) the extension tool used to tighten the piston and the bottom plug during core recovery, and b) the water jet used to remove the sediment surrounding cores.

produce the jets of water used to dislodge sediment around the core. The assembly is connected by collapsible fire hose to a gasoline-powered centrifugal water pump in the boat (Homelite XLS-1½, Charlotte, North Carolina). The vertical tube of the jet assembly is ~30 cm shorter than the core tube, thereby preventing disruption of the bottom of the core by the water jets. The circular portion of the assembly is placed over the exposed end of the core after the piston is tightened, and is worked into the sediment by a diver.

A removable collar with handles can be attached to the top of the core tube to provide divers with an effective means of gripping the tube when removing it from the sediment (e.g., Sanders 1968; Martin and Miller 1982). Alternatively, a pair of holes in the top of the core tube can be used to hold a horizontal rod that is attached to a line to the boat, allowing retrieval of the core with a shipboard winch (in this case the piston is not allowed to reach the top of the core tube during deployment). In either case, a second compression plug is inserted into the bottom of the tube by a diver as soon as possible after the tube is pulled out of the sediment; the fit of the plug is tightened after insertion by turning its compression nut, using the extension tool if necessary. Divers ascend with the core to the boat for recovery, ensuring that the core is kept vertical at all times in order to prevent disruption of the upper core.

Cores can be subsampled either with subcores inserted through holes drilled into the top of the core tube, or by sequentially removing sections of the sediment as the core is extruded using the lower compression plug, slightly loosened, as a piston.

Results and Discussion

We have used this coring technique with sediments composed of carbonate mud (Kaneohe Bay, Oahu, Hawaii) and terrigenous mud–slit (Tomales Bay, California). Porewater concentrations of dissolved ammonium and dissolved inorganic carbon (DIC) from a 3.3-m long, 7.5-cm diameter core taken near Tommasini Point (station 16) in Tomales Bay, California, are shown in Fig. 3 to demonstrate the quality of the cores possible with this method (see Smith et al. 1991 for the location of this sampling site).

The observed covariation in porewater concentrations of ammonium and DIC is consistent with the expected release of ammonium and DIC during organic matter oxidation in the sediment (e.g., Nissenbaum et al. 1972). The porewater DIC:NH_4^+ ratio is 19.7 (r^2 = 0.97), which is markedly different from the C:N ratio of 7.4 measured for suspended particulate matter in the overlying water column in Tomales Bay (Smith et al. 1991). This difference is presumably due to the preferential removal of nitrogen from settling particles at the sediment surface (e.g., Martens et al. 1978).

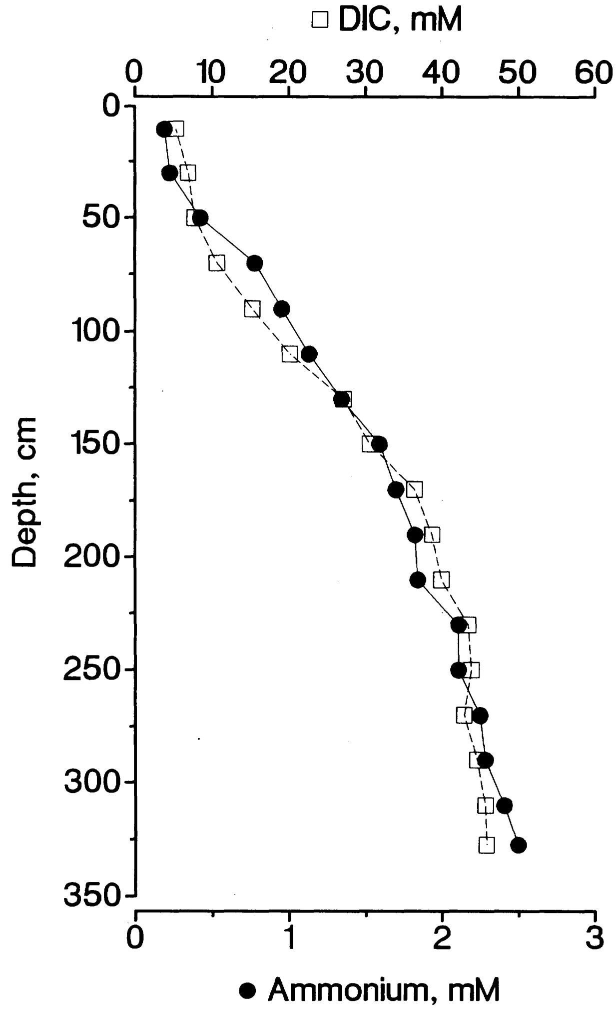

Fig. 3. Dissolved ammonium and inorganic carbon porewater profiles from a core collected near Tommasini Point, Tomales Bay, California. Porewater was obtained with a sediment squeezer; ammonium was measured spectrophotometrically, and inorganic carbon was measured manometrically after porewater acidification and cryogenic trapping.

The smooth concentration profiles in the upper portion of the core indicate that there was minimal disturbance of the sediment-water interface during coring; similarly, there was apparently little disruption of the lower portion of sediment during coring operations, as evidenced by the lack of erratic data due to exchange of porewater and overlying seawater. In addition, the use of a piston minimizes the effects of sediment compaction and friction, which continue to be an issue of controversy with gravity coring (e.g., Blomqvist 1985; Crusius et al. 1993).

The corer can be used under fairly difficult working conditions. We have used it in currents of up to ~2 knots (~1 m s^{-1}), and with minimal water clarity (<1 m visibility). The design presented here could be used in intertidal sediments subjected to only light wave action, but stronger versions could be fabricated for rougher conditions. The bottom-time limitations of SCUBA diving restrict the practical operating depth of operations to ~25 m unless mixed gas or saturation diving techniques are used.

Conclusions

The piston-coring technique described here is a low-cost method of obtaining relatively long, non-compacted cores from fine-grained sediments using a variety of small boats or ships. It requires only three personnel (two divers and a boat operator); however, additional crew are helpful for handling long cores. Although coring operations are limited to diver-accessible depths, the ability to manually insert the core into the sediment allows for minimal disruption of the sediment-water interface. In addition, the technique allows high-quality cores to be collected with lengths much longer than those possible with gravity corers.

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