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A Light-Weight Spring-Driven and Hydraulically-Damped Multiple Piston Corer

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A light-weight multiple piston corer to meet increasing coring needs in areas where R/V access is limited, is designed and discussed. Hydraulically-damped and spring-driven piston system not only retrieve virtually undisturbed surface sediments but also facilitate the recovery and subsequent operation including pore water extraction and core slicing on board the ship. It is designed as compact, light-weight and easy to dissemble that whole gear can be carried by small passenger vehicle yet it permits thick-walled core tube for thermal insulation or large opening core tubes. Because single spring instead of heavy weights of conventional gravity-driven multiple corers is used, this device is very simple and cheap to construct.

INTRODUCTION

Recent developments in electrochemical techniques that facilitate simultaneous measurement of major redox sensitive ions in the uppermost sediment with submillimeter scales (Luther III *et al.*, 1998) are breaking the barrier in sediment chemistry. Currently a recovery of undisturbed sediment corers is rather critical for the accurate determination of target chemical species to understand a complex and condensed sedimentary system. A variety of coring devices has been developed through the years to retrieve intact sediment surfaces. Box corers (Soutar *et al.*, 1981; Froelich *et al.*, 1983) with suitable modifications are capable of collecting relatively undisturbed sediments under ideal sampling conditions. These cores have additional advantage of recovering a large sample and can minimize temperature change that would alter pore water chemical distributions.

Disadvantages of box corer arise mainly from the water overlying cores, which is a rarely representative of real bottom water due to exchange during core retrieval. Additionally, surface sediments may be disturbed due to sloshing of overlying water during core recover. Bow wave created by the frame can, under certain circumstances, significantly disturb sediment surface during core operation (Jahnke and Knight, 1997). For example, Shirayama and Fukushima (1995) reported consistently low nutrients concentrations in overlying water of box corer compared to those of multiple corer, suggesting a contamination of surface water in box corer. Such facts severely hamper the study of sediment surface. Hydraulically-damped corers were developed that allowed a slow and controllable penetration of core tube into sediment. These types of devices made considerable progress for the acquisition of undisturbed sediment surfaces. Further refinement of design (Pamatmat, 1971) and adoption of piston (Barnett *et al.*, 1984) gave birth to cone shaped multiple corer capable of recovering up to 12 cores simultaneously. However, all the above designs are susceptible to a certain degree of core shorting, especially for fine sediment due to friction. To overcome such an undesirable effect, Martin *et al.* (1991) used electric motor to drive sediment barrel. But the whole system becomes too complex to be used widely. Recently Jahnke and Knight (1997) introduced a hybrid design of preceding corers. They combine the desirable aspects of gravity-driven and hydraulically damped designs that can ensure slow penetration and minimum bow effect still keeping the simple design.

Although big and heavy multiple coring devices prevailed the market, European scientists involved in North Sea Project tested and improved existing simple, smaller and lighter gravity corers. Latest addition in this family is the Gemini twin corer from Finnish Institute of Marine Research (Finnish Institute of Marine Research, 1992). As the name stands for, it retrieves two core samples instead of one that others

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do. It closes barrel bottom without external core-catching devices that intact sediment surface can be retrieved with a slow speed operation.

We report here a new design of sediment corer that accommodates current interdisciplinary research needs and ameliorates operational restrictions. For the former, we aimed at the least surface disturbance during the recovery including intact water-sediment interface, and for the latter we tried to improve *in situ* maneuverability of the corer. We replace weight of predecessors with a compact spring to reduce the size and weight of the corer. Other features inherit the former designs. The outcome is as small as to be carried by passenger car, as light as to be operated by bare hands, even so it provides as many as six cores simultaneously. This should make coring an easy task in the coastal areas and lakes where modern R/V access is restricted. Overall core quality is aimed not to be the state-of-the-art but to satisfy a wide range of current benthic studies.

INSTRUMENT DESIGN

A schematic description of the corer is shown in Fig. 1. It is constructed with aluminum central hydraulic cylinder and steel tripod. It stands on 1.6 m on the adjustable legs that angled outward, away from the core barrels. Each foot is made of a dough-

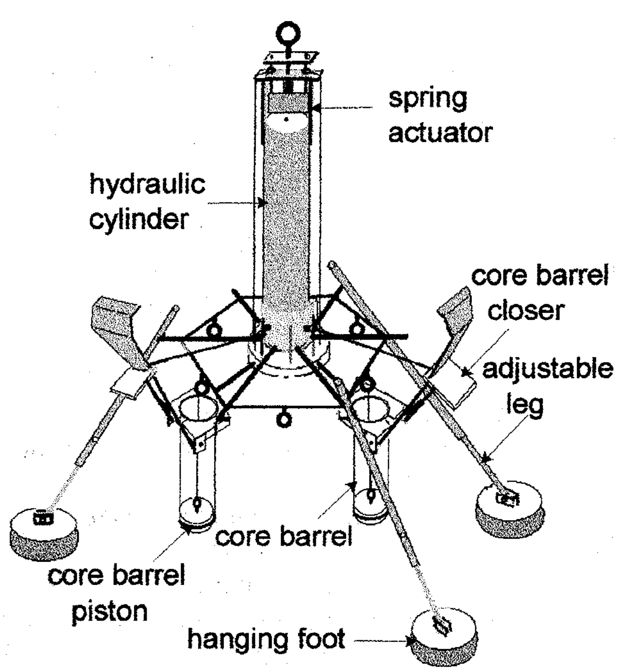

Fig. 1. Schematic diagram of a spring-driven, hydraucally damped multiple corer. The unit is approximately 1.6 m tall and 1.2 m wide.

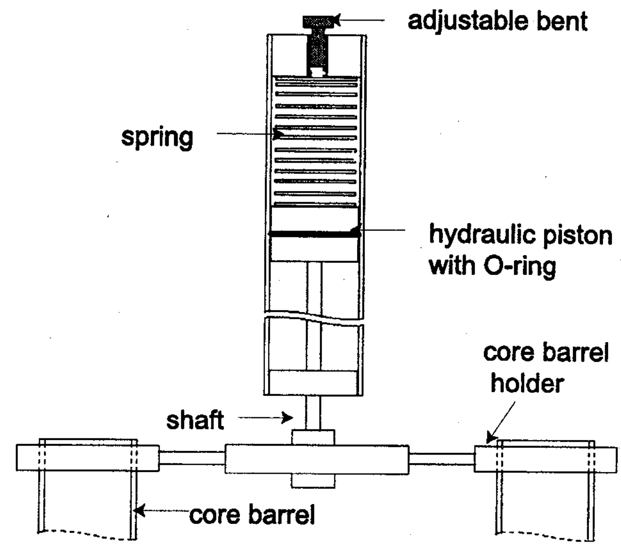

Fig. 2. Schematic diagram of the hydraulic cylinder.

nut shaped plastic. Screw holes on the leg allow the position of the piston to be optimized relative to sediment-water interface.

The core barrels of up to six with bottom closer are attached to the central hydraulic cylinder via core barrel holder that are connected to hydraulic piston shaft in the central hydraulic cylinder. Manually compressible spring is located inside the cylinder. When actuated, spring is hydraulically damped due to a slow filling of cylinder by incoming seawater (Fig. 2). A vent hole and screw at the top of central hydraulic cylinder can adjust the speed of core barrel insertion. A piston with a head O-ring sealing was quite sufficient for the hydraulic damping of spring. From the experiences of previous workers (Jahnke and Knight, 1997), slower penetration of core barrel always resulted in better samples in terms of smearing, core shorting and surface agitation. Slower rate of travel would also minimize bow wave-generated disturbances from the feet to propagate to the coring area before the core barrels reach the sediment surface. The prototype version of frame weighs about 30 kg, which is much lighter than gravity-driven types of around 400 kg or more.

Presently, core barrels of 80 mm inner diameter with 90 mm outer diameter are used, however, it is designed to accept wide variety of core barrels with simple modification. A polyethylene piston is machined to fit each core barrels. By eye examination, a single O-ring seal at the piston head was successful to prevent leaking and exchange of overlying seawater and dissolved gases (Fig. 3). Core barrels are easily detached from the core assembly simply by

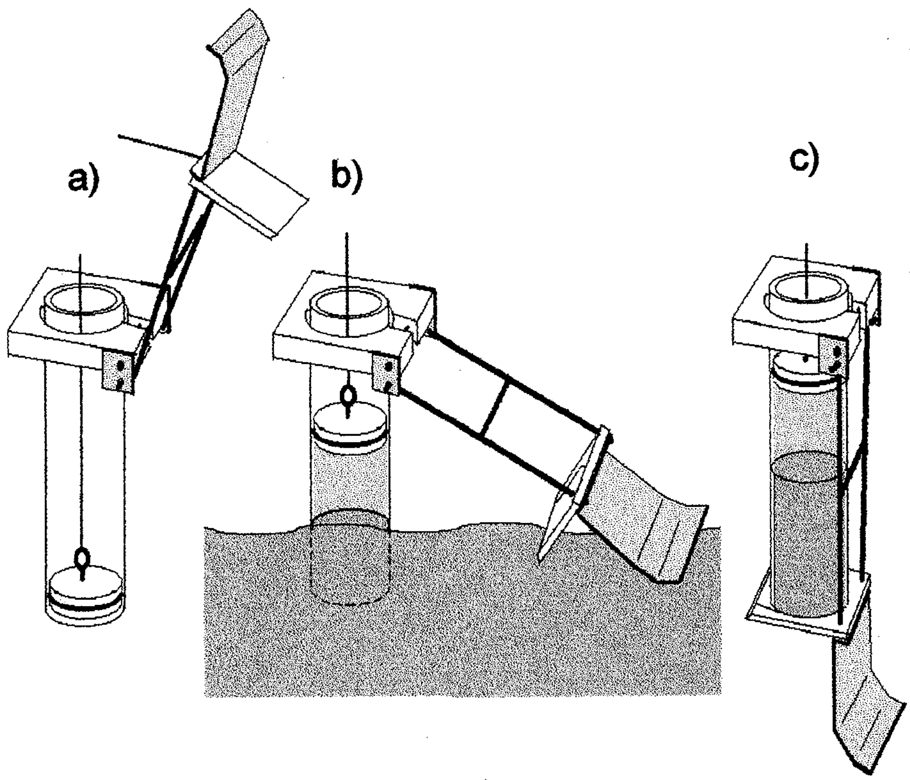

Fig. 3. Core barrel with closer assembly: a) launching, b) sediment pentration mode, and c) retriveal mode

loosening one finger-tightening bolt, which minimizes the contamination of sample.

The present version of spring-actuated corer is the first of its kind. Spring is compressed manually by two persons and tethered to release-lock assembly at cylinder top. A brass block with attached pins and springs is kept in lock position when pulled upward. When the corer touches the bottom, tension due to pulling is released that the weight block is pushed down by springs, which releases tether and the main cylinder spring is actuated. Prior to deployment, pistons are positioned at the bottom of the core barrels. When spring is actuated only the core barrels penetrates slowly into sediments, leaving piston fixed at original position. By adjusting the height of piston from the feet, sampling with or without overlying seawater is possible. Our test version is adjusted to sample top 20 cm sediment with 10 cm overlying seawater.

External wings attached to core barrels are designed to close the core barrel bottom. Wing connected to barrel piston shaft by a wire is set to a upward position prior to launch (Fig. 3). During the coring, wing with closure plate is released and lowered to the bottom by its own weight. Subsequently when corer is pulled up from the ship, plate of the wing is designed to close the barrel bottom by hydrodynamic friction generated by wing and seawater during the transit. It also helps keeping sediments from eddy erosion during the lifting at shallow depths down to 50 m tested.

The overall design of corer is simple and easy to construct. Since weight has been replaced by a spring, dissembled corer can be easily packed in the cargo department of small passenger car. It essentially consists of simple mechanical parts that can be readily replaced. This makes the corer inexpensive to construct and maintain. While exact costs depend on the choice of metallic parts and local machine shop rates, our prototype device was built with a very limited budget of $1,500.

It is worthy of mentioning that this spring-driven, hydraulically-damped multiple corer is designed not as a state of the art sediment recovery but to facilitate coring at sites where practically no routine sediment coring was possible. For example, either R/V or a heavy gravity corer is not available in many places like shallow coastal area and lakes. So there are inevitable trade off between the core quality and the accessibility. Most of all, our working version has a limited penetration depth of maximum 30 cm. Through our experiences we estimate that manually compressible spring-driven corer can, at best, retrieve 40 cm long sediment sample. Thus sampling with our device is confined to the surface sediments. However, for the most coastal regions where organic matter input is one or two order of magnitude higher compared to the open ocean, short but intact sediment samples should be able to provide valuable information on the pollution status, major biogeochemical cycles, sedimentation and benthic communities. Multiple sampling capability and lightweight feature will find more applications in the near future.

TEST APPLICATION

Demand for chemical analysis of dissolved matters in pore water is ever growing from elements to chemical species regarding the fate of materials introduced in the ocean. Current data quality about the pore water chemicals is highly dependent on field techniques such as sediment sampling and pore water extraction. Although there exist several techniques to extract pore water from the sediment they all requires sediment slicing. Since it requires often sophisticate apparatus to prevent air contact and subsequent extraction, working in a small vessel is not an easy task. Since transporting core samples to a land-based lab also faces a problem of core agitation, temperature variation etc., we tried to develop a simple, contamination free pore water extraction technique without sophisticate instruments.

Major distinction between existing method and ours is that we rely on the gentle pulling of vacuum vial rather than high pressure pushing to extract pore water. A new pore water extraction assembly is shown schematically in Fig. 4. It essentially eliminates sediment extrusion, subsequent slicing and external power. The core of our novel technique is an adoption of a fine porous medium that acts as a conduit and a particle filter simultaneously. Ideal material for this purpose can be made from fine Teflon beads or high quality glass powder. By molding these materials by heating, one can make porous rod to meet ones own research need. However, we couldn't find such manufacturer around so that we use a substitute for test purpose. A synthetic polyester fiber rod that widely used as tip in marker pens possesses excellent features for our purpose; narrow, sturdy and clean. We were able to extract 5 to 10 ml of pore water in about half an hour. Provided with modern analytical instruments, these should be enough for the measurement of target chemical species, for example, several redox related ions and or nutrients, etc. Results of pore water nutrient measurement are shown in Fig. 5. Currently we are able to extract in 5 mm sediment interval, which is difficult to achieve by a conventional core slicing methods.

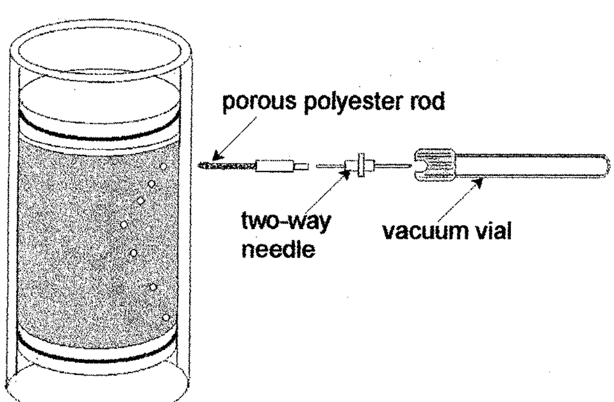

Fig. 4. A novel porewater extraction kit. Whole core can be extracted simultaneously.

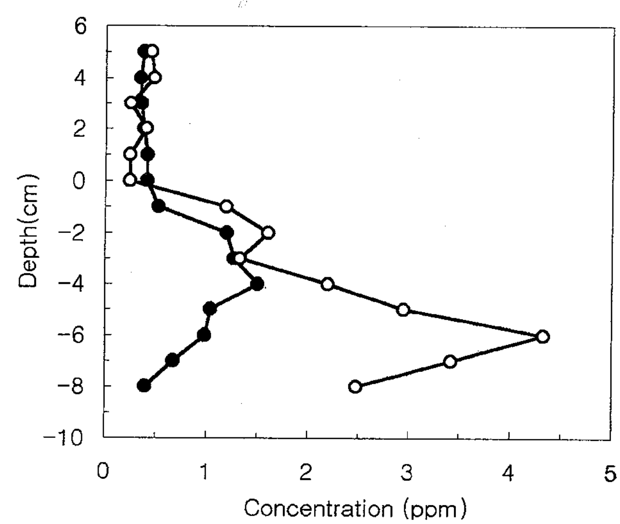

Fig. 5. Depth profiles of dissolve iron (open circles) and phosphate (filled circles) in overlying seawater and sediment sample collected near Gadeug Island. Pore water was extracted using our new extractor shown in Fig. 4.

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