A new coring method: controlled penetration speed

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ABSTRACT: During geologic and geotechnical surveys which require obtaining samples of seabeds using a corer, usually one of the standard methods for coring is used: gravity or free fall using a trigger. For scientific and geotechnical studies the most important objective is to obtain a very high recovery/penetration rate. A new method of coring will be discussed, which further reduces possible disturbances in the column of sediment samples, especially at the top, by varying the speed of penetration. This theory has been verified in an Italian port where core samples were taken using a Piston Corer in 6 meters of water with 8 meter long barrels; the piston was attached with a kevlar rope to a stationary point and the corer was dropped using a winch so that the speed can be changed and controlled, thus allowing the speed to be increased during penetration, in order to obtain a high quality sample.

1 INTRODUCTION

It is well known that the seabed can be read as an archive of human activity (Blomqvist, S., 1985). In particular, the twentieth century left the largest contribution of trash from various anthropogenic activities connected to the current technological and demographic development (Benn, A. R. *et al.*, 2010) and from nuclear experiments. Furthermore, the study of marine geohazards (landslides, tsunamis, earthquakes) can be applied not only to science but also to technical fields for designing works at sea, such as ports or offshore structures, for laying hydrocarbon pipelines, electric cables or telephone lines. Along with these sectors, there is also the study of coastal evolution, and environmental and pollution studies.

Given all this demand, it has become necessary to develop new instruments and appropriate methods capable of retrieving high quality sediment samples and which minimize further disturbances in sedimentary layers and eventual contamination.

Furthermore, geotechnical trials carried out using corers, known as the direct method, can offer much insight when correlated to data obtained using the indirect method of geophysics, such as those taken from the Sub Bottom Profiler.

Gravity or Free-fall methods are used in geological and geotechnical surveys which require obtaining samples seabed. Both techniques can be used for traditional coring, with the gravity samplers, or generally, free-fall from a limited height by a trigger with the piston corer (Kullenberg, B., 1947; Busatti *et al.*, 1980; Lunne, T. & Long, M. 2006). Because of the need to recover longer and less disturbed samples, piston corers were originally introduced by Kullenberg (1947). These were considered as an improvement on simple gravity type devices. The piston is usually either directly connected to the main cable or there is an independent piston cable (Lunne, T. & Long, M. 2006).

Recently, the use of piston corers has been studied in-depth by several institutes and private companies, analyzing the results based on the length of the free fall, the slack, the elasticity of the cable, and the variable weight of the core head with the purpose of achieving better penetration. Deeper penetration, however, does not always correspond to higher recovery rates. The laboratory tests on these samples will give results that are not representative of in situ conditions and will give incorrect parameters (Lunne, T. & Long, M. 2006). For scientific and geotechnical studies, the most important objective is a very high recovery/penetration rate.

A new method of coring will be discussed in this paper, which further reduces possible disturbances in the column of sediment samples, especially at the top, by varying the speed of penetration.

2 METHODOLOGY - CONTROLLED PENETRATION SPEED

The idea for this new method came out of the study of samples taken in the past by various private companies and institutes of scientific research, where the top of the cores -the most recent from a geological point of view and therefore the least solid- was often disturbed (Bourillet *et al.*, 2007), due to the extra suction that corresponds to an over-distortion or even the total loss of the material. This contamination, caused by the action of the traditional coring methods, was at times excessive. In order to improve this traditional method, penetration of the instrument must begin at a low speed and as the depth of penetration increases, so must the speed of the descent, in order to overcome the friction which grows as the thickness of each sedimentary layer increases. It would therefore be necessary to have a low initial penetrating force, which slowly grows as the coring continues. To increase the push (given that it is not possible to increase the mass of the instrument once it is in the water coring) it is necessary to increase the speed. Based on the water depth, this methodology can be applied in different ways: in shallow water the corer is connected to a winch or a crane with variable speed control, while the piston is tied off to a fixed point on board with a very resistant rope; this rope runs down the length of the corer and attaches to the top of the piston. The entire operation is described in detail in the next paragraph.

In very deep waters, this technique is not possible as it would not be easy to manage two cables or ropes in the water during the coring operation. Therefore, a special instrument has been created to resolve the problem. In this paper, however, this issue is not discussed, as here the focus is on the method used in shallow waters with a case history presented in the following paragraphs.

2.1 *Controlled penetration speed in shallow water*

To use this method, also called "*Angel Descent*", one must connect the cable of the winch or crane (1) to the eye-bolt (2) of the corer head, while the piston (3) must be connected to a high resistance kevlar rope attached to a fixed point on board (5) which must be high enough above the water line. If the exact depth of the water is known as well as the dimensions of the piston, it is very easy to calculate how long the rope should be. The characteristics of the rope make it easy to change the amount of slack based on water depth, just by making a knot in the rope itself at the correct length and attaching said knot to the fixed point, which can be, for example, an eye-bolt on the crane or A-Frame.

When the corer is vertical and ready for the drop, the winch begins lowering the corer at a slow speed; in this moment the kevlar rope is slack (Fig.1).

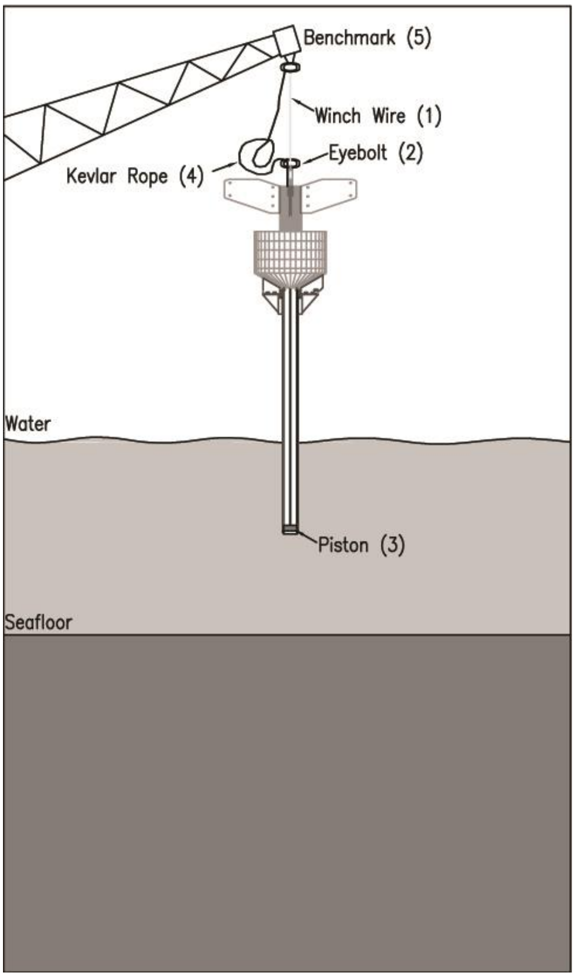

Figure 1. Set-up of Corer

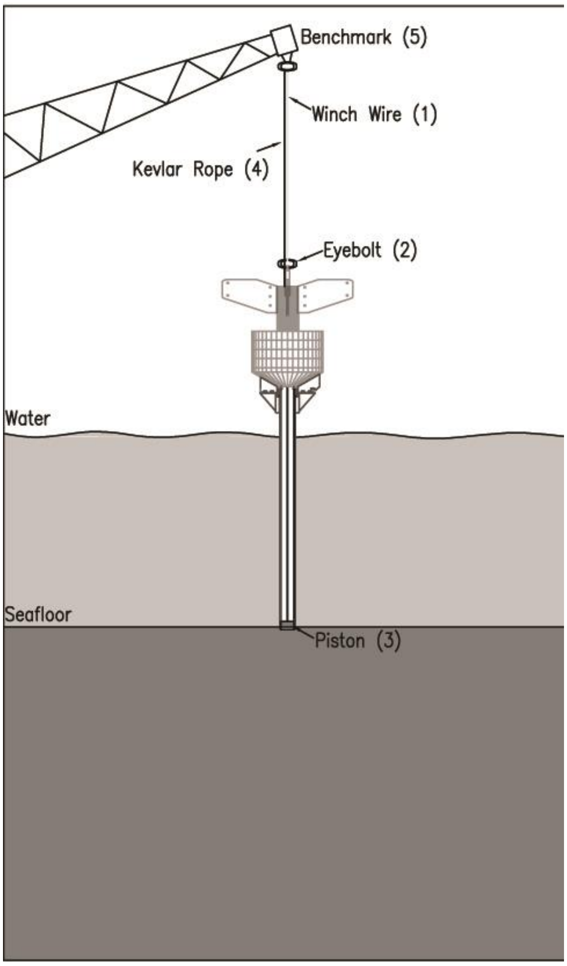

Figure 2. Initial coring phase

This operation can happen also out of water. In fact, the rope in question will become taught in the exact moment when the piston touches the seabed (Fig. 2).

The piston is mobile but stationary at this height, while the coring tube penetrates (Fig. 3). In this phase, the winch begins to increase the speed of descent.

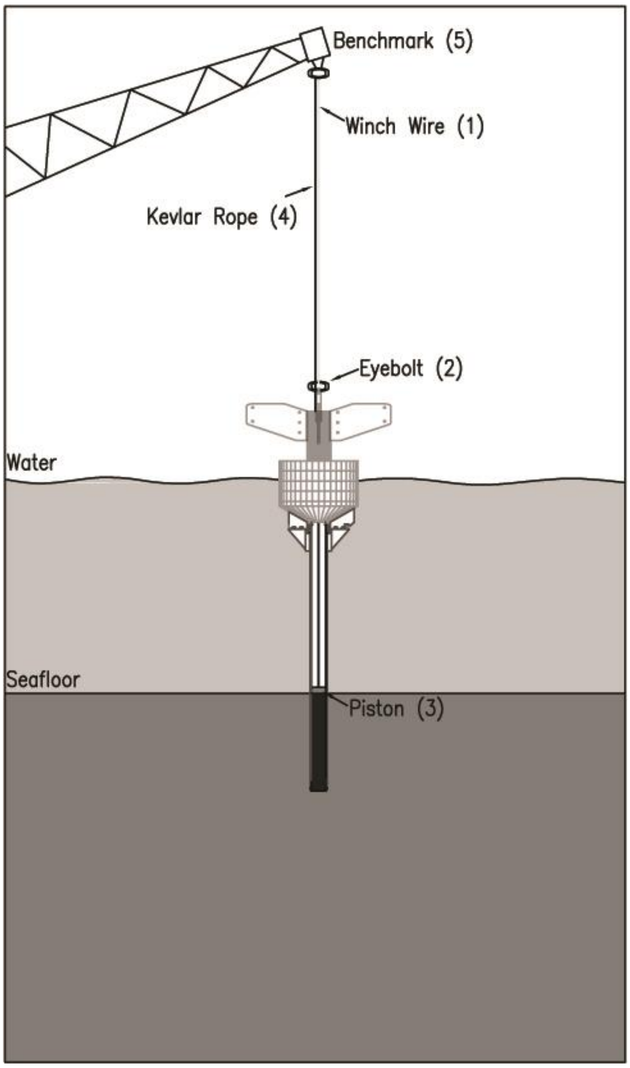

Figure 3. Corer's penetration

The corer continues to penetrate until it hits more substantial sedimentary layers. If it does not encounter said layers, the corer stops when the piston meets the base of the head of the corer (Fig. 4). At this point, the rope is taut, while the winch cable is slack.

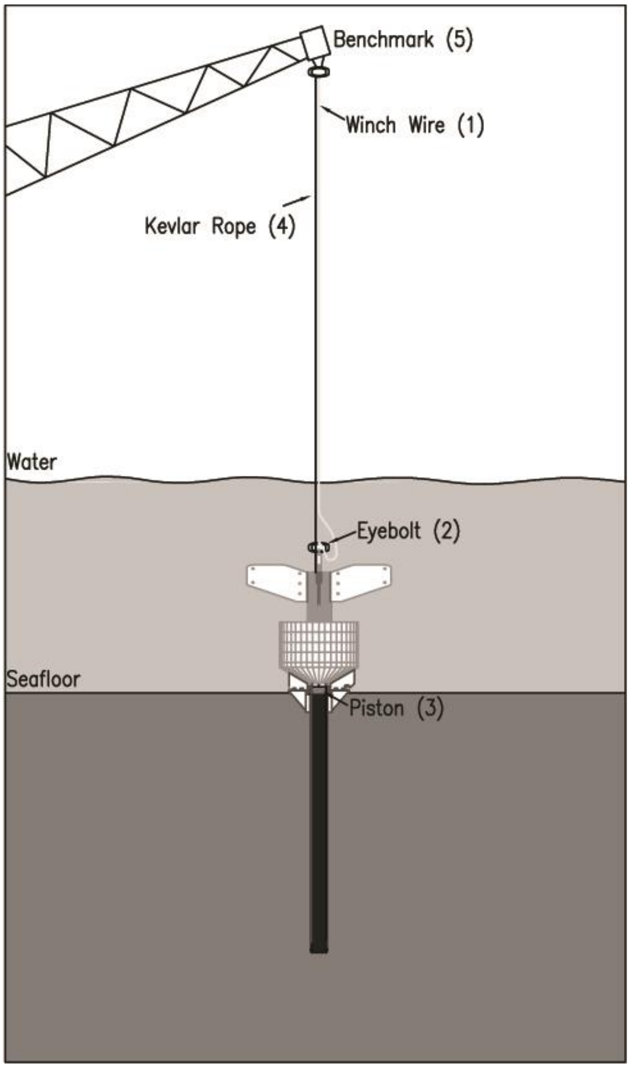

Figure 4. Final coring phase

2.2 *Results and Discussion*

This new methodology was used in Italy in 2011 for sampling of a small area where a new port will be constructed. The aim of the job was to recover a representative sample of the first 6 meters of sediment in less than 30 meters of water depth. This result had never been achieved in the past by other companies using traditional methods.

In the mobilization phase it was decided that the piston corer should be configured with 8 meters of tube length - instead of the 10 meters requested - in order to obtain the goal of a 6 meter sample. Certain of its yield, the Carma® Piston Corer was chosen as the instrument for the job, with a 5 meter tube connected to a 3 meter one. Given the geotechnical data obtained with CPT and the geophysical data taken by the client at an earlier time, the corer head was outfitted with 4 weights for a total weight of 1850 Kg, in order to overcome the friction of the sand layer present at 0.5m into the seafloor. Standard configuration was used for the mobile piston: 4 active pins and 4 fixed pins, attached to a Dyneema SK75 rope 14mm in diameter, made up of high tenacity polyester and kevlar, with a breaking point at 10800 Kg.

Two samples were requested: one in 7.0 m water depth and the second at 5.6 m water depth. The corer was positioned vertically off the side of the boat, while the difference in height between the fixed point to which the rope would be tied, and the water line was measured. Once adding this to the depth, the necessary length of the rope was calculated and tied off. The winch of the crane was connected to the eyebolt of the corer (Fig. 5).

Figure 5. Start Corer's deployment

The "Angel Descent" began with the nose of the corer 4 meters above the seabed. The speed of the winch was very low initially and then progressively increased during penetration.

The first core perforated 7.30 m below the 7.00 m water depth, with a final coring sample of 6.74 m, equal to a recovery index of 92.3% (Hvorslev, 1949).

In the second sample, in 5.60 m of water basis, the total penetration of the corer was 8.00 m with a recovery of 7.13 m equal to a recovery index of 92.6%. This result was also obtained on the first try. In this case, the kevlar rope prevented the corer from penetrating too deeply into the sediment, thus avoiding any eventual disturbance of the sample (Table 1).

Measurement of the velocity of penetration of the corer was possible deduce thanks to the video done with a ROV (Fig. 6).

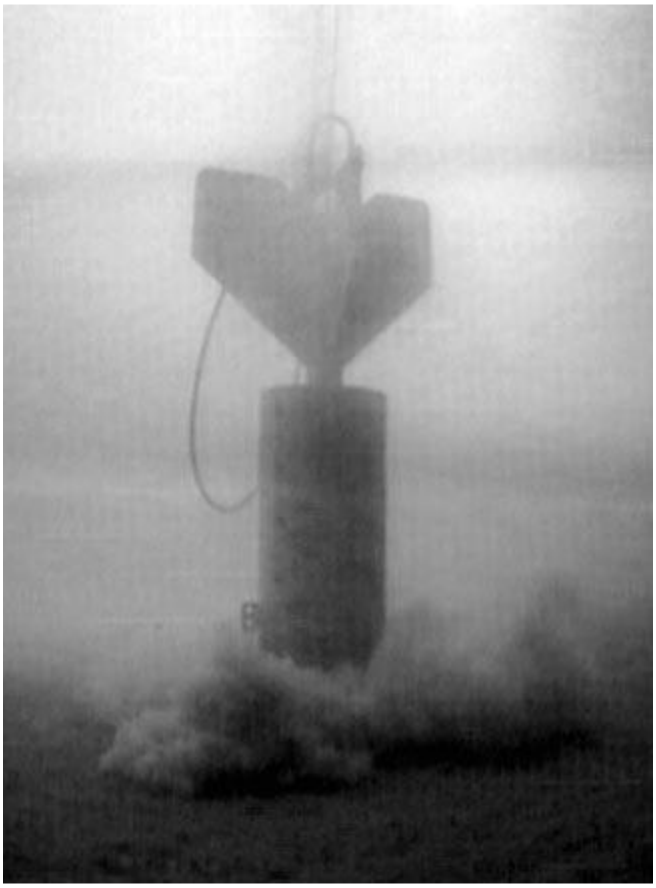

Figure 6. Corer's head at end of penetration

In screening the film, it was possible to see that the penetration speed of the first 3 meters of the tube was at 4.17 m/s, while that of the next 5 meters was at 3.27 m/s (less due to friction). The average speed of penetration was 3.56 m/s, lesser than speeds recorded in the past when using traditional free fall techniques, which reached more than 8 m/s.

A more detailed analysis revealed that the velocity at the moment of impact of the corer with the seabed was only 1.9 m/s, and then it steadily climbed up to 2.5 m/s when the first 3 meters of the tube had penetrated (average velocity considering 0 seconds at zero speed when the nose was 4 meters from the seabed). In the next 2 meters of penetration, the speed increased slowly, -due to friction- until it reached an instantaneous velocity of 2.70 m/s. The last 3 meters of penetration registered a practically constant instantaneous velocity as compared to the last speed measured: 2.72 m/s. This data confirms all that has been asserted thus far in this paper.

The samples taken were made up mostly of sandy silt; near the top and at 6 meters silty sand. Plant fragments were, however, present throughout the sample column.

In conclusion, it should be known that the method described in this paper is patented.

Using the methodology described above, the corer can be modified based on the seafloor sediment characteristics.

2.3 *Configuration variables of the Piston Corer*

The configuration of the Carma Piston Corer (registered patent as utility model; Holder: Research National Council–Rome, Italy) has three variable components. These components are: the weight of the corer head, the length of the corer tube and the configuration of the active piston (Registered patent as design patent; Holder: Research National Council–Rome, Italy). In shallow water, other variables do not need to be considered; the elasticity of the cable is insignificant and the height of the free fall -along with the slack- do not come into play when using this new methodology.

The head has a minimum weight of 650 Kg and can be increased by adding up to 5 weights each one weighing 300 Kg, for a total maximum weight of 2150 Kg.

The tubes have various lengths running from 1-6 meters, and can be combined to make up a maximum length of 30 meters thanks to the particular connecting joints.

The piston can be configured differently for each coring project due to the fact that the suction levels applied to the core sample may be varied. Inside the piston, there are 8 perforated holes which are then closed by the same number of mobile pins, -thus allowing or not allowing as the case may be- a definite amount of water to pass from the upper chamber to the lower one (Magagnoli, A., 2003). It is possible to change the ratio of these mobile pins (which can move out of their sockets to allow the water to flow freely through the piston) in relation to the fixed pins (which keep the holes closed and do not allow the water to pass).

Thanks to all of these features, this new *Angel Descent* methodology permits accurate recovery of fine sediments even in extreme shallow water conditions. Up to date, taking coring samples under these prior conditions was difficult due to technical and safety limitations this endeavor implied; both in regards to personnel safety as well as to the instrument security.

3 FUTURE DEVELOPMENT

This new methodology is being developed for deep water sampling to.

A special winch, connected to the main cable, located just above the trigger, will allow *the penetration speed to be controlled*. The configuration variations of the corer would remain more or less unchanged, given that the height of the free fall will be set to zero, as will the slack. The elasticity of the cable will not, however, be insignificant, but this problem can finally be solved using Angel Descent. Usually, the cable snaps back once released, after it stretches out due to the weight it sustains, depending on the depth of the job at hand.

For coring, this problem results in a loss of efficacy, given that the cable connected to the piston creates vertical tension in the opposite direction of penetration. Thus, the piston accelerates upwards, creating a very low pressure inside the core barrel moving downwards through the sediment (Skinner, L.C. & McCave, 2003), instead of working at the level of the seabed. With this new method, this problem is solved because the mass of the corer - which weighs on the main cable - gradually declines: the speed of the cable recoil will be less than the speed of penetration of the coring tube in the seabed, thus allowing a much better result to be obtained.

Furthermore, electronic instruments will aid in an in-depth study of the dynamic of coring; for example, an accelerometer connected to the corer will record acceleration (and deceleration) data during the penetration phase. A careful analysis of the data will allow the user to compare different coring methods and to mathematically understand which method works best.

4 CONCLUSIONS

Today, offshore activity is part of many business sectors: from research, to the oil industry, to mining, laying cables, building infrastructure and studying the environment. The need for accurate and undisturbed core samples has led to the development of this new coring method with controlled penetration speed (Angel Descent), in order to obtain sediment samples with more accurate outcomes.

The results of the project carried out in Italy are listed in the following table:

Table 1. Sampling results

	Water depth m	Penetration m	Recovery m	Recovery %
1° core	7.0	7.3	6.74	92.3
2° core	5.6	8.0	7.13	92.6

The data show a high value of core sample recovery, especially considering the shallowness of the water, and the difficulty of coring with instruments that measure more than 7 meters long. The instantaneous velocity of the Angel Descent reached 2.72 m/s at the end of the coring procedure, with a constant increase of speed that went from 1.9 m/s to 2.5 m/s during the first 3 meters of penetration, then reaching 2.7 m/s after 2 more meters. In the following figures, the data taken from the second core sample are shown:

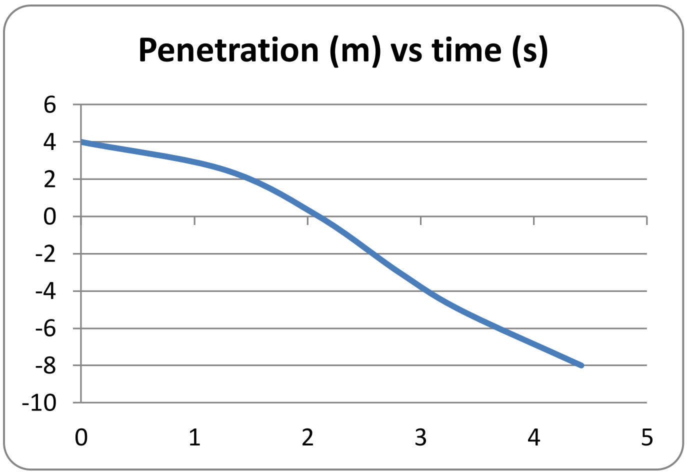

Figure 7. Space-time graph, where zero represents the level of the seafloor.

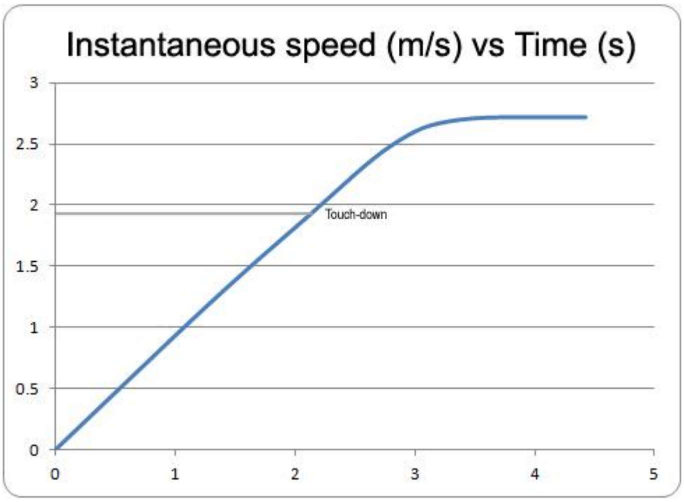

Figure 8. Instantaneous speed-time graph, where on the axis, zero represents the start of the angel descent.

The parameters which should be set up during preparation of the corer are the following: weight of the head, length of the corer tube and configuration of the active piston. In shallow water, no other variable needs to be considered: the elasticity of the cable is insignificant and the height of the free fall and the slack do not come into play with this new method, which makes the setup of the instrument easier.

The method of controlled penetration speed can also be used in environmental studies, for example in the dating of undisturbed samples for determining the time-line of human affected events when dealing with environmental issues such as contamination and pollution.

This method also makes it possible to take deep core samples in shallow water, where up until now it was technically impossible. In the near future, this same technique will be applied to any depth of water, thanks to the aid of a special winch.

5 ACKNOWLEDGMENTS

I am grateful to Angelo Magagnoli for his continuous ideas, discussions and lessons based on his lengthy experience on board various oceanography ships for various projects.

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