to coat samples in order to make a surface conductive, especially when gold, carbon or a coating machine are not available.

The resolution of the gel-coated samples is a little less than that of the gold-coated samples, but it is better than or equal to that of the carbon-coated samples (Fig. 1). Minerals can be identified and confirmed using both SEM and optical microscopy without any modification of the sample. A particular mineral or interesting area can be located easily with the optical part of the SEM (if available) that is comparable to an optical microscope.

ACKNOWLEDGMENTS

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# A SENSOR FOR MEASURING EROSION AND DEPOSITION[1]

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## INTRODUCTION

The processes of sediment transport and deposition entail questions of the frequency of transport, the threshold of transport, the migration of bedforms, and the sedimentation and resuspension of sediments carried in suspension. The study of these processes demands the simultaneous monitoring of the process agencies, i.e., the current and the waves, and the response at the sediment-water interface.

In the past, two main approaches have been used to measure changes in bottom elevation in the wave-influenced environment: optical methods, using a time-lapse camera or a video-camera (e.g., Davies 1985), and acoustical methods, using a high-frequency echo-sounder mounted at some distance above the bottom (e.g., Wright et al. 1986). However, not even an echo-sounding frequency of 1 MHz can give a resolution better than a few millimeters, which is not always quite adequate (e.g., in areas of low intensity processes, plane bed transport, or when studying ephemeral mud blankets). Both the echosounder and the cameras are quite bulky and will disturb the flow pattern if they are put too close to the point of study. At longer distances the cameras are severely limited by suspended sediments, notably at just those events that are of most interest. Furthermore, video cameras produce an enormous amount of data that is not readily interpretable by computers.

The present instrument, the "sedimeter" (patent pending), is also optical in that it uses light as an information-carrier, but due to its operating principle it is not disturbed by suspended sediment or colored water. The disturbance of the flow pattern associated with it is small and rather constant.

## DESCRIPTION

The sensor in the instrument is a transparent (acrylic) tube, equipped with infra-red optical-backscatter detectors at 10 mm intervals so as to give overlapping measurement zones (Fig. 1). The relative elevation of the sea-bed in the spot where the instrument is put is measured at a desired time-interval and registered in the data logger. The tube material and the medium inside the tube are selected so that no reflections will occur from the sensor itself (the refraction index will be the same as that of water).

The detectors (Sharp mod. GP-2S02 photo-interrupter), only 4 mm in diameter, each contain an infra-red light-emitting diode (LED) and a photo-transistor with an IR-filter, to avoid disturbance by visible light. Since infra-red light is subdued very quickly in water, the instrument can be operated in water of only a few meters depth, even in broad daylight. The principle in itself does not restrict the maximum depth for the sensor.

Each measurement entails registration of the backscattered light off each LED/photo-transistor pair (Fig. 2), by lighting each LED separately, while the photo-transistors are connected in parallel to the analog/digital converter. In the schematic diagram of Figure 2, the addressing of a specific LED is done by means of a 4 × 4 grid from transistors that are controlled by a serial-parallel converter. The advantage is that only 4 wires are needed from the data logger in order to light the LEDs, and 8 wires on the sensor PC-board, as opposed to 17 all the way if each LED had its own wire.

The geometrical and electrical arrangement of the sensor makes resolution better than the distance between the individual detectors; theoretically a resolution of less than a tenth of a millimeter can be achieved (0.0001 m). In a laboratory experiment, the addition of a single sand-grain could be detected. This means that minute changes on the bottom immediately beside the sensor can be monitored.

The returned signal is a function of the reflecting properties and concentration of the sediments. A plot of the registered data will therefore indicate both the level of the bottom and the approximate concentration of sediments in the water close above the bottom. When several measurements are plotted together in a 3D-plot, minute changes of elevation, as well as in turbidity, will easily be detected by visual inspection (Fig. 2).

The mechanical framework that has been used for the sensor is shown in Figure 3, and Figure 4 illustrates the way in which it is deployed. A diver can mount it in a sand bottom in a few minutes.

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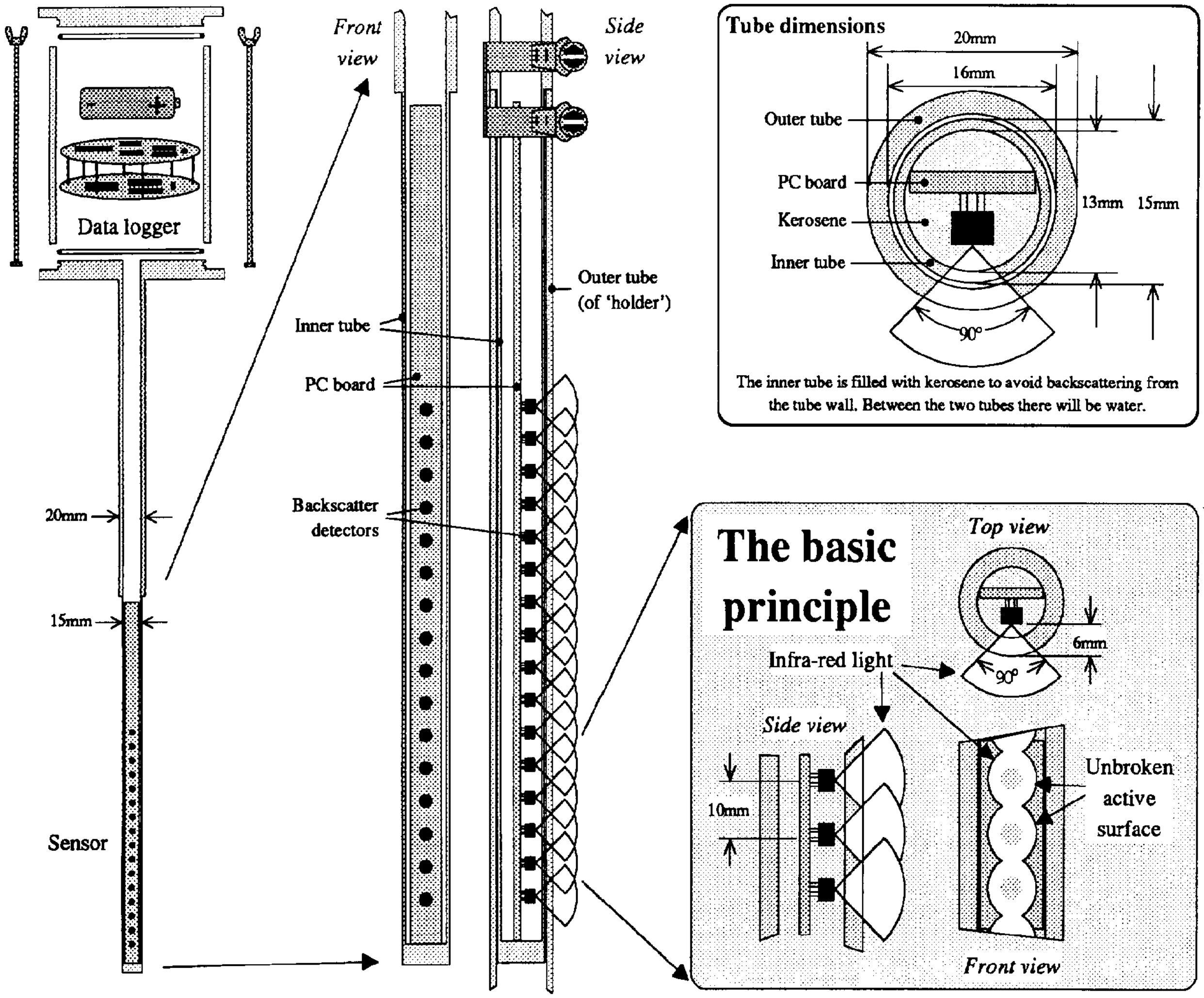


FIG. 1.—**Left:** The "sedimeter" instrument unit, consisting of a sensor and a data logger in a water-tight housing. **Center:** Front and side view of the sensor, with 16 backscatter detectors mounted on a PC-board. The side view also shows the tube of the holder and the fastener (at the top) that is made from two stainless steel hose clamps. **Top right:** The holder (outer tube) is needed both to anchor the instrument and to get a sand-free hole into which the sensor (inner tube) can be inserted. **Bottom right:** It is the unbroken active surface that enables a resolution to be obtained that is better than the distance between individual backscatter detectors. Note that the dimensions given in this drawing are only suggestions, and other combinations are also possible.

## DISCUSSION

The "sedimeter" is a simple yet versatile tool used to detect sediment transport, its greatest advantage being that it will detect an almost negligible change in bottom elevation. It can also be used to measure the migration of bed forms, using an array or even a matrix of "sedimeters." It is also suitable for detecting settling and resuspension of ephemeral mud blankets (cf. Floderus 1989), for measuring the thickness of the sediment-enriched bottom water, and for monitoring the consolidation process of those sediments.

A conceivable drawback with the sensor design is that the 20-mm sensor rod will disturb the flow patterns around it. This effect has been studied in a flume and in field tests in the Baltic Sea at 19 to 24 m depth. In the latter environment, a small depression of about 1 mm around the tube was observed on each inspection. The flume tests, with a unidirectional current, gave a somewhat deeper scour (2 to 3 mm), but the scour was constant in relation to the surroundings. The conclusion is that the *variations* in elevation are correctly measured, and as long as the measurements are made relative to an arbitrary datum, it is unimportant if the *absolute* values are slightly in error.

During an application under the winter ice of Lake Erken, the slow accumulation of ca. 5 mm of mud, the "winter carpet," was interpretable

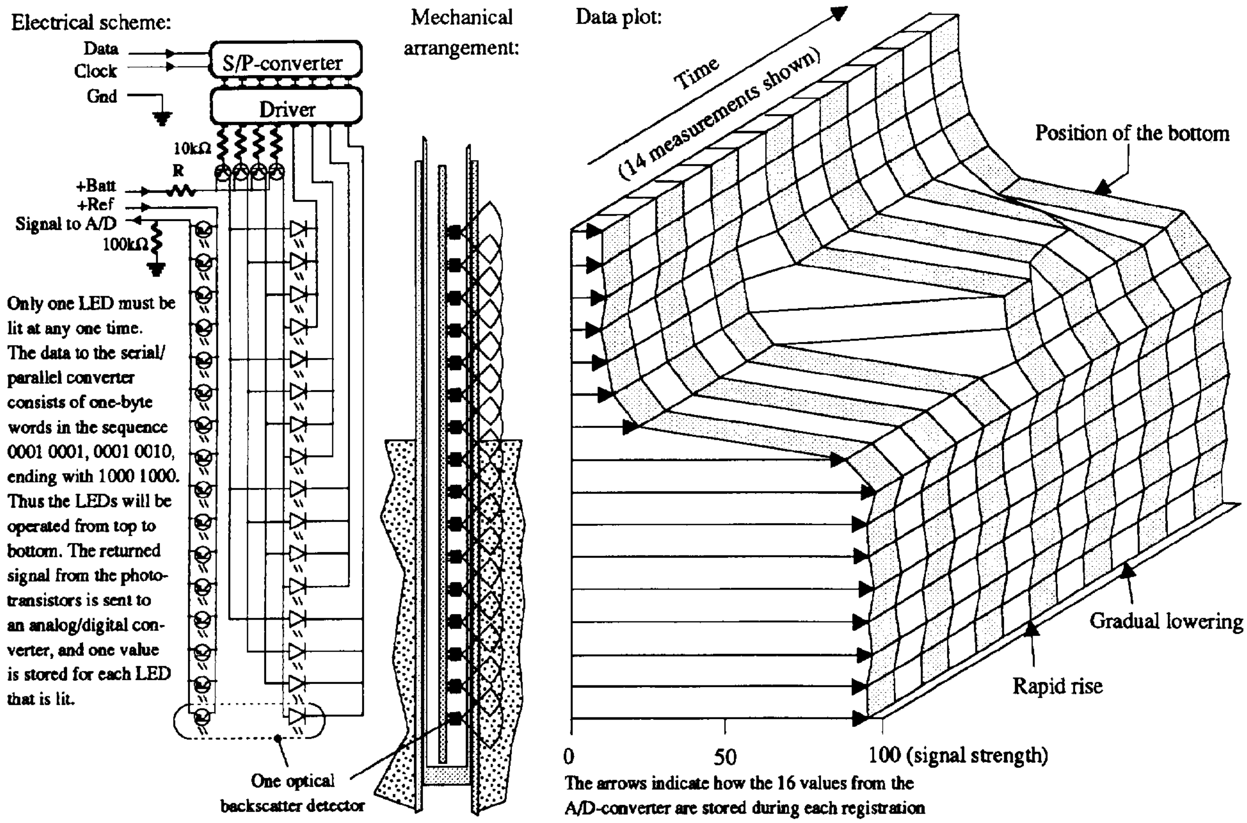


FIG. 2.—**Left:** The "S/P-converter" can be made with a dual 4-bit shift register with buffered outputs, e.g., 4015, and the "Driver" is a darlington drive, e.g., ULN 2803. Four PNP-transistors are needed to "invert" the current. With a value of "R" of 316 Ω at a "+Batt"-voltage is 9 V, each LED needs to be lit ca. 1 ms in order to get a stable signal out. **Right:** A three-dimensional data plot visualizing the data output from the instrument shown in the center. The signal strength is indicated as an index value, where 0 is the lowest and 100 the highest attainable. The sensor must be calibrated in order to transform this index to a precise value of bottom elevation or sediment concentration, but as a fair estimate (to within a millimeter or so) the position of the bottom is where the index 50 is passed, as shown to the far right.

from the data (water depth: 2 m). In the Baltic Sea operations, episodes of wave ripple formation were recorded, as well as episodes of current-induced sediment transport. During a week of very calm weather and weak currents, a 10% gradual rise of the data from the detector at the sediment-water interface occurred. By inspection of photographs taken in the beginning and at the end of that week, the increased reflectivity could be linked to the gradual accumulation of mud in the interstitial spaces of the sand (Erlingsson 1990). This demonstrates the instrument's excellent ability to continuously register subtle processes as well as to catch the action during storm events.

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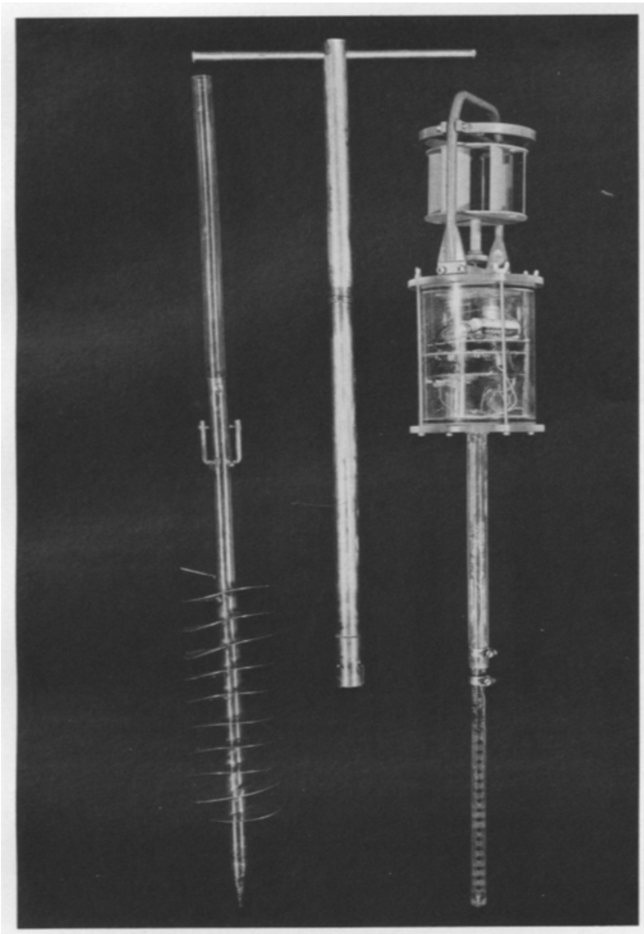

FIG. 3.—The "sedimeter" holder (with the transparent tube at the top), handle and instrument unit. The latter is equipped with an optional Savonius current rotor on top.

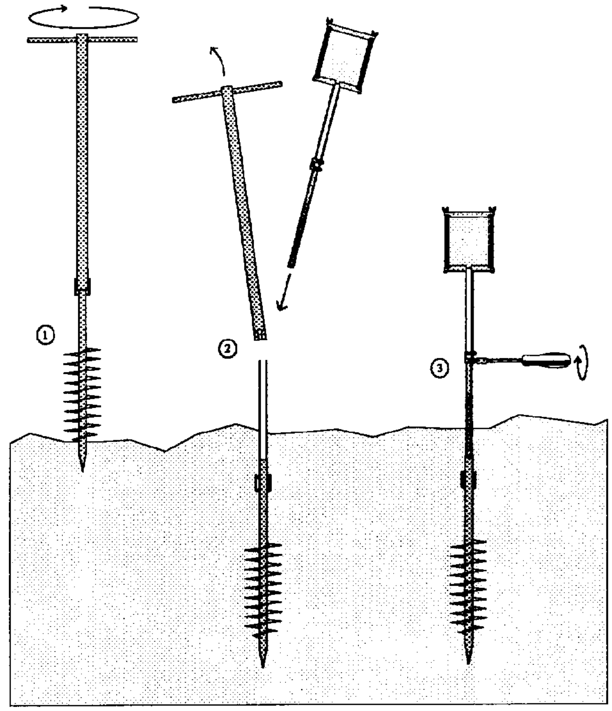


FIG. 4.—Employment of the "sedimeter" on the sea floor. When it is time to retrieve the instrument for data collection and battery exchange, a new instrument can immediately be placed in the old holder, thus enabling a continuous data series with a common datum. The holder can be reused at a new location after exchanging the acrylic tube.