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The limnogeology-ETH coring system

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ABSTRACT

Various methods are available for coring in lakes. We have developed an integrated coring system based on a modified Kullenberg poston-corer principle which is particularly useful for multiple coring in deep lakes. The selection of sites is guided by concurrent high-resolution (3.5 kHz) continuous seismic profiling.
The system is modular for simple transport, and includes a very reliable tripweight gravity corer which uses the same plastic liners as the piston corer. Piston-core lengths are variable in 2, 4, or 5 m sections up to 16 m.
This system has been successfully deployed in glacially deepened perialpine lakes (Lakes Zürich, Zug, Greifensee, Lucerne, Walensee, Constance, Murten, Neuchâtel, Geneva, Thun, Brienz, Maggiore, Lugano, Iseo, Garda, d'Annecy, Bourget and Ammersee), deep rift lakes of Africa (Turkana, Albert, Edward, Kiwu), Lake Ohrid (Jugoslavia), Lake Van (Turkey), Qinghai Lake (China), and in very shallow hypersaline lakes Urmia (Iran) and Great Salt Lake (USA).
Following numerous requests, this paper describes the system concept and constructional features that have been refined over the last 12 years. Development has stressed increasing simplification and increased reliability.

Introduction

The ETH-limnogeology (limnos = lake) program for the study of geological processes and problems in modern lakes, began in 1968 with the usual difficulties of finding proper core sampling equipment. Technical publications of such instrumentation were rare. Experience with systems on deep-sea research vessels showed that marine equipment is overdimensioned for most coring in lakes because of the limited space on smaller vessels. In contrast, limnological-supply companies generally offer only light-weight, gravity coring equipment for deployment from small boats.
Our original interests were to obtain at least 7 m long cores in Swiss lakes in order to define the facies development of subaqueous slides and turbidites [14]. In order to accomodate borrowed equipment for a heat-flow measuring campaign of the alpine foreland [9, 29] we were forced to turn to marine piston core systems but adapt these to the special requirements of mobility and handling in lake-oriented research. The Mackereth corer is an alternate system for conveniently operating from small boats and is based on compressed air [1]. We had to reject this system, then in development, because of its limitations to depths less than 100 m due to air-pressure and hose requirements.

We chose to construct a modular Kullenberg-type corer [17] system loosely based on modified plans from Reineck [20] and information gleaned from published papers [2, 21]. U. Briegel was responsible for the original design.

This piston corer has been modified over the years and has matured into a useful routine tool for limnogeological research. In addition to all of the larger perialpine lakes [9, 10, 12, 13, 18, 19, 27] it has been deployed in deep Rift Valley lakes: Kivu, Albert, and Eduard [6]; Turkana and Malawi (Johnson, per. comm. 1986); 450 m-deep Lake Van, Turkey [7]; 300 m-deep Lake Ohrid, Yugoslavia [22]; in Austria [23, 28] and other small alpine lakes [5, 11, 30]. With minor alterations, we have also obtained excellent suites of 6 m-plus cores from the shallow (7–12 m deep) hypersaline lakes Urmia, Iran, and Great Salt Lake, USA (e.g. [15, 25]), as well as salty Qinghai lake, China (Kelts, per. comm.)

The system can be subdivided into the following parts which are described below.

A: Piston corer
B: Trigger gravity corer
C: Winch retrieval
D: Raft vessel
E: Site selection by 3.5-kHz seismics

Limnogeology ETH piston corer

The conceptual requirements of the piston corer design required:

- reliablitity at all water depths
- modular, interchangeable parts
- maintenance free
- air freight capability
- sediment taken in continuous, oriented PVC liners.

The piston corer breaks down into six main units:

1. the head
2. the core barrel
3. the trip system
4. the ropes
5. the tripweight corer
6. accessories

A variable-length, stainless-steel core barrel assembly with a PVC liner inside is attached to a variable-weight head (see fig. 1). It is suspended from a counterbalance lever-trigger mechanism until the lever is unburdened once the trip weight is supported on the lake floor. The optimal freefall interval is determined by the length of the tripweight rope and is usually 3 m.

The system uses three cables rather than just two as in most marine applications. This allows a complete release of tension on the piston. The trip-lever mechanism may be detached from the main cable by a dropped messenger weight, whereupon the mechanism slides down the cable onto the head. This is important when working from a small raft, with limited vertical clearance under a crane or tripod. The piston remains stationary within the core tube, even if penetration has not been complete. With the detachable weight stand, we have been able to take up to 10-m cores with improvised cranes having as little as 2 m vertical clearance. Figure 2 shows the unit components laid out. In summary, the component parts of the six main units are:

1. The head (fig. 3)
   1. The removable weight guide and shackle hairpin
   2. The weightstand, with beveled feet and grip ring
   3. 2 massiv cotter pins

2. The core (fig. 4)
   4. Upper core barrel with flange and insert to head
   5. Building block core barrel, variable 2–6 m sections up to 16 m
   6. Joint manifolds for barrel sections
   7. Steel alloy sunken allen screws for joints
   8. Crown mount with threads and set pins
   9. Core nose bit
   10. Core catcher
   11. Piston
   18. PVC 58.5 × 61.5 mm diameter core liners

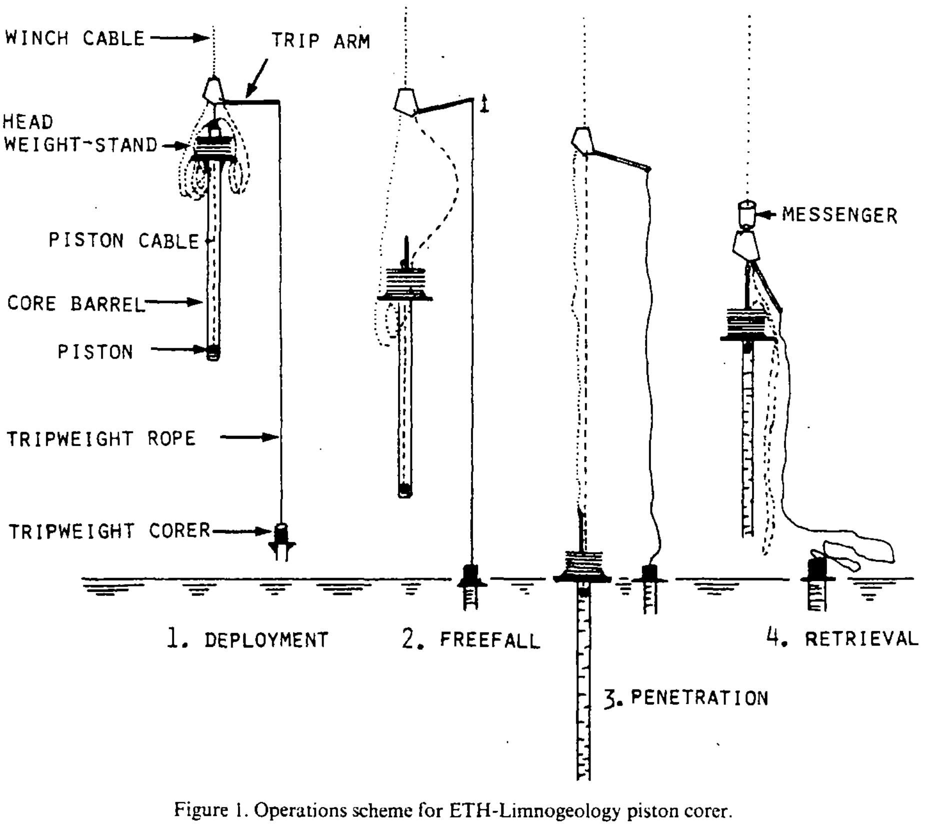

Figure 1. Operations scheme for ETH-Limnogeology piston corer.

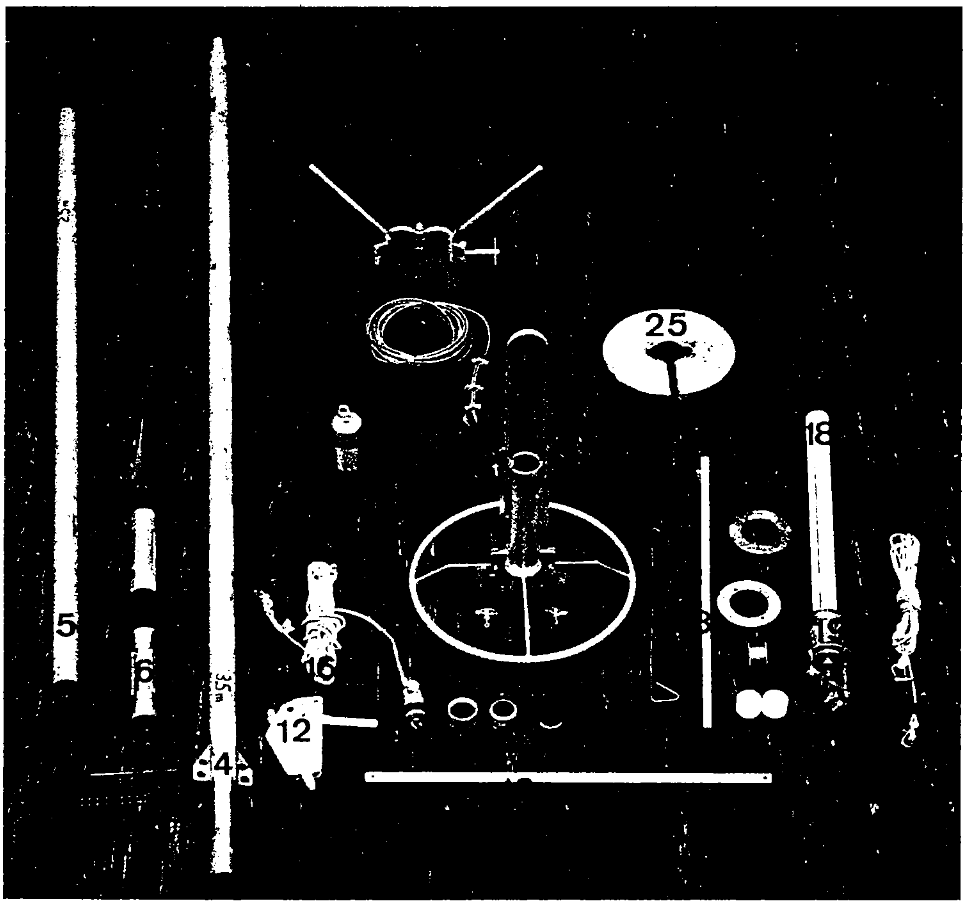

Figure 2. Overview of component parts of ETH-Limnogeology piston corer. (See text; no 23 is a 1-m stick for scale.)

3. Trip system (fig. 5)
   12. Trip lever fulcrum and sliding wedge cable jammer
   13. Removable, variable length counter balance arm
   14. 6 kg messenger, slides down cable to release cable jammer

4. Ropes
   15. Main cable: 7 mm Rotex, rotation free crane cable with eyelet
   16. Piston rope: 8 mm prestretched braided nylon
   17. Trip weight rope: 6 mm prestretched braided nylon

5. Tripweight corer (fig. 6)
   18. PVC core liner as above (uses left overs)
   19. Trip weight corer head, and valve seals
   20. Exchangeable lead weight rings, 25 to 35 kg

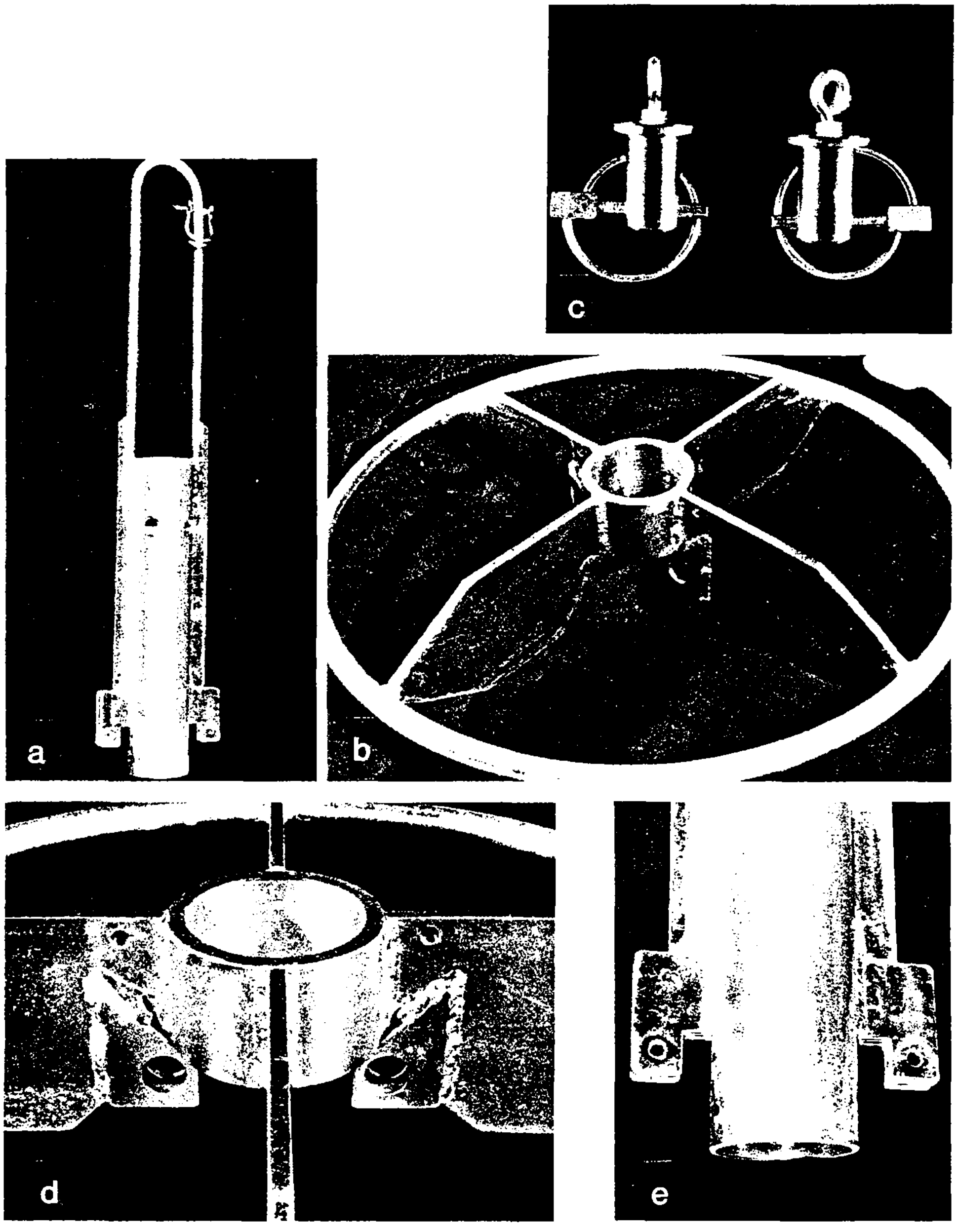

Figure 3. Constructional details of core head, weight stand. Pipe diameter is 70 mm. a: dismountable vertical guide with flange; b: base plate with supports and safety feet for grab ring; c: 20-mm scotter pins for flange; d, e: close up of base plate center.

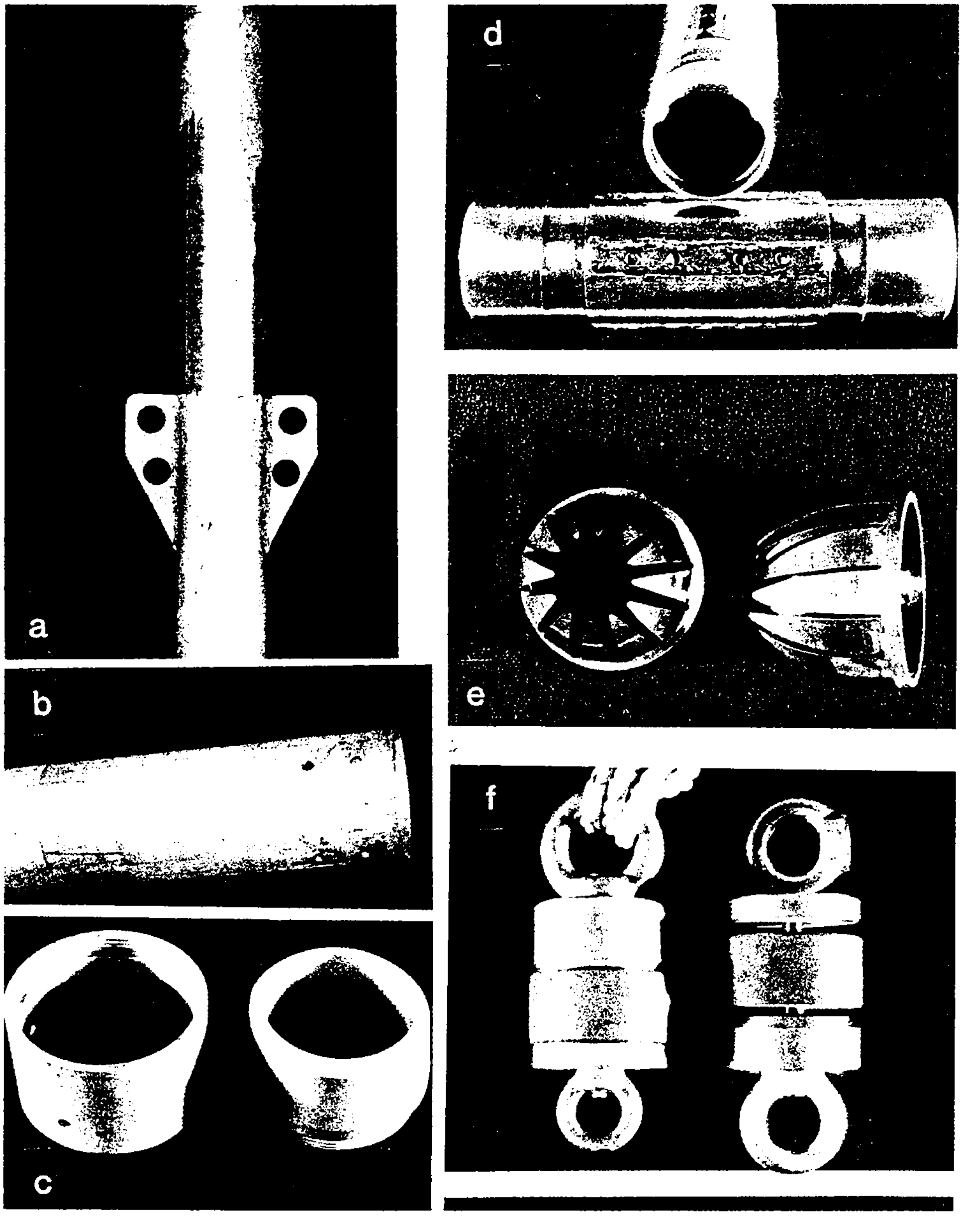

Figure 4. Constructional details of core barrel. Diameter of pipe is: 64 × 70 mm. a: Core barrel flange. Upper holes secure to weight stand, lower set to lift core barrel on deck and secure after detaching head. b: Tip of barrel, with eylets and guides for core muffins (d) or attachment of crown and bit features (c). e: Core catchers of various strength spring-bronz. f: Piston with adjustable with neoprene seal.

6. Misc.
21. PVC liner caps
22. PVC sealing tape
23. Meter stick for cutting liners
24. Hock to retrieve piston rope through core head
25. Lead weight plates: 35 kg each, stackable to 500 kg
26. Core barrel clamp to secure core barrel while removing weights

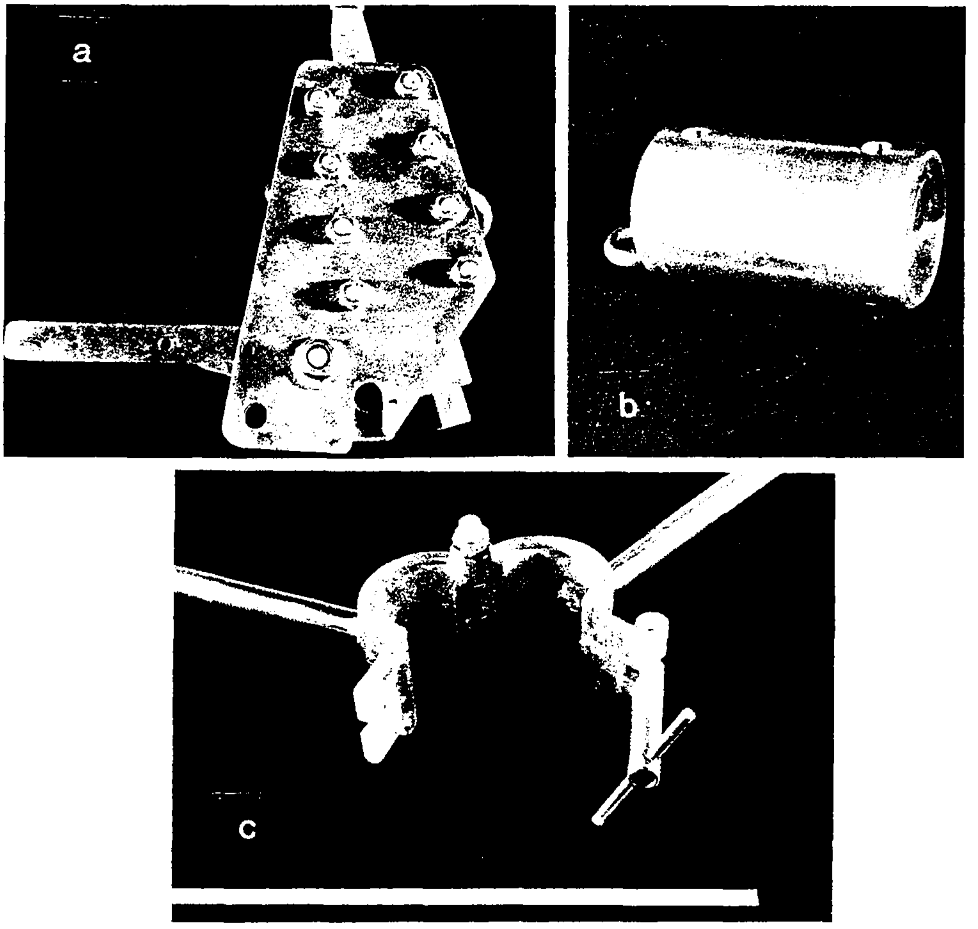

Figure 5. Details of trigger and retrieval mechanisms. a: Trip mechanism with pivot for removable balance arm and holes for safety pin. Sliding wedge to clinch against cable. b: Messenger. A 6 kg steel ram which is dropped from the surface to release the wedge in the trip mechanism after core penetration. The tension on the piston is thus also released. c: Quick-attach core barrel clamp to support the core during removal of the weight stand from the upper barrel sections.

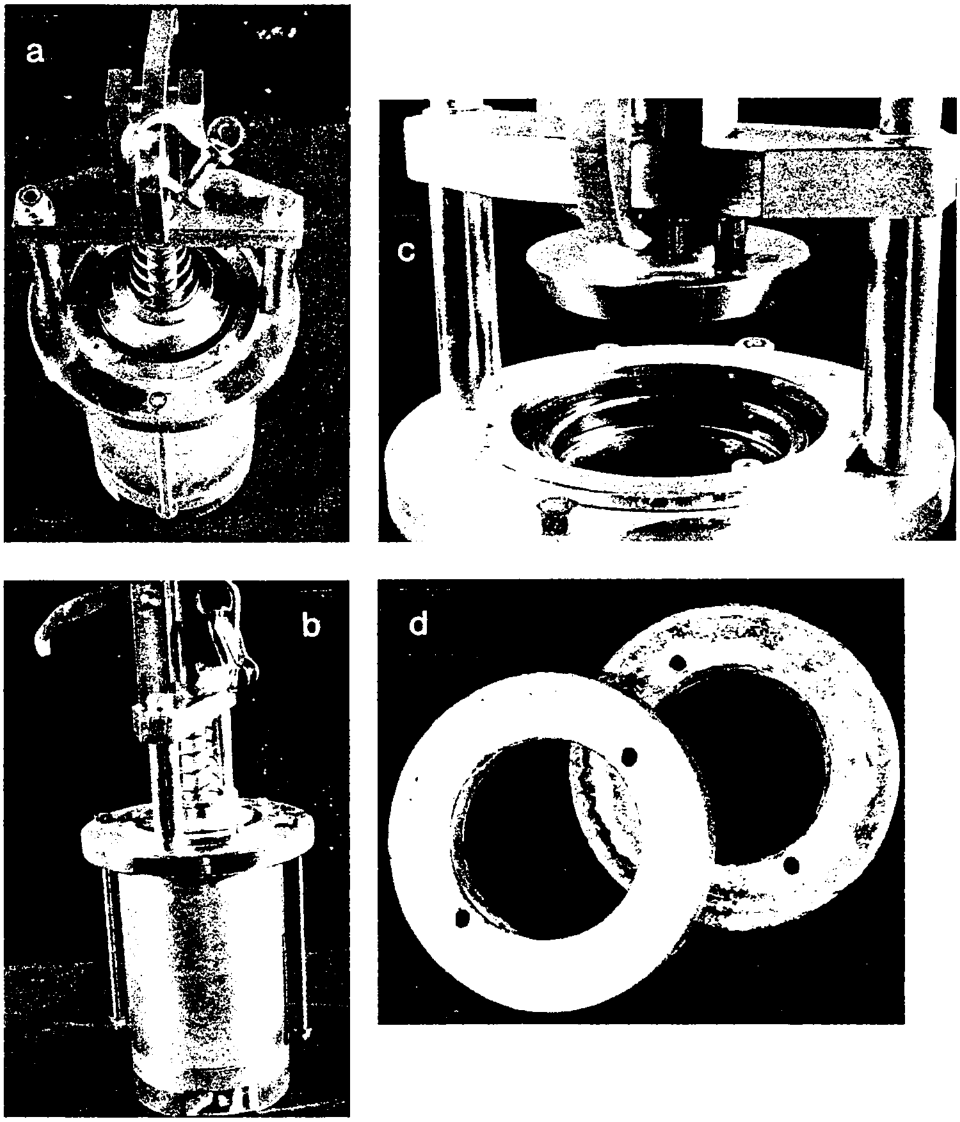

Figure 6. Details of tripweight corer which also serves as a practical gravity corer to recover the surface 1 m of sediment undisturbed. a: Cantelever shackle attachment and spring-loaded wide-mouth valve. b: Side view with weight attachment bolts and lower clamp ring with seal to hold left-over liner sections from main corer. c: Detail of trigger and valve. Air tight seal after penetration is effected by a spring supported rubber V-ring. d: Lead weight rings.

Monitoring

During operations, a 100-kHz echograph is commonly used to monitor the coring progress. Once the assembly is in the water, a safety pin is pulled from the trip weight arm and the corer lowered as in figure 1. A 7 mm rotation-free steel cable suspends the system. Figure 7 gives an example of the resolution whereby both the trip weight and main piston corer are visible. Any rotation of the system can be watched, and at about 6 m above bottom the unit is stopped and let pendle to stability. The extra traces on the retrieval echo (fig. 7) are due to the trip mechanism and twisting of the trip weight corer around the barrel. One can follow clouds of mud after penetration, and mud cakes falling. This record also permits a good estimate of depth of penetration.

Navigation

Generally sites are located by radar, and images recorded from 5-min interval photographs of the screen. Projecting these on to a base map, and adjusting to contours gives excellent accuracy ($\pm 1\%$). Horizontal sextant measurements are maintained as a backup.

Site selection

Because of the complexity commonly encountered in lakes, a single core is often difficult to interpret in terms of a sedimentological history. Coring programs are thus run concurrently with a high resolution seismic profiling program. Figure 8 shows an example of the possibilities. Layers such as B which are beyond the reach of a core barrel at one site, can be cored on the modest hill to the right. The significance of pockets of homogenous

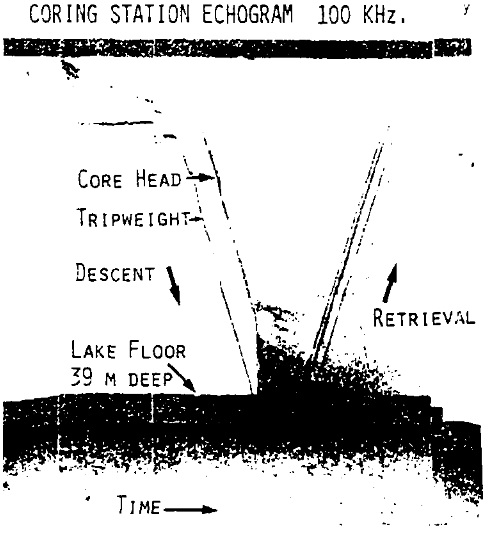

Figure 7. Monitoring of coring progress with a 100-kHz echograph.

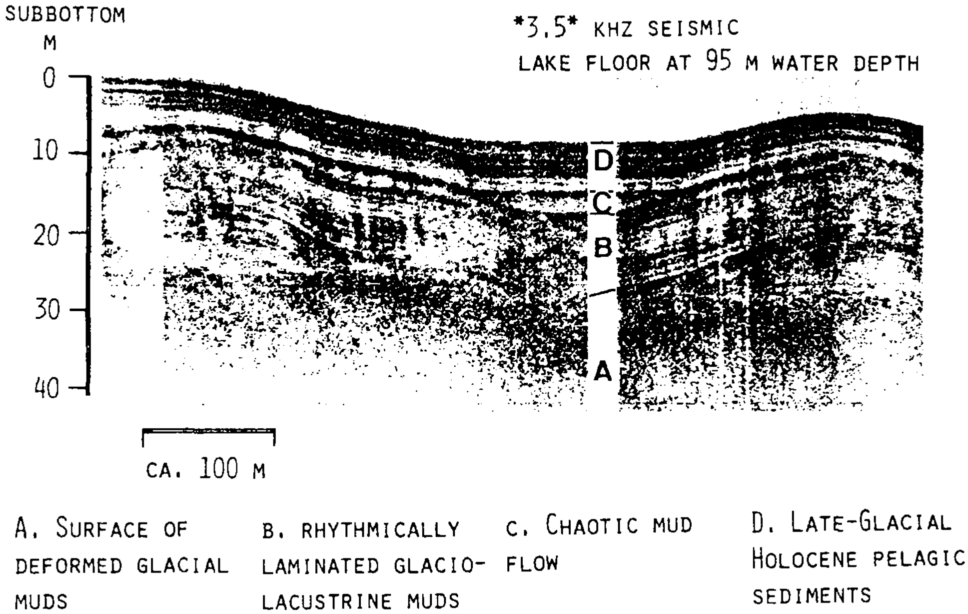

Figure 8. Example of a 3.5 kHz high resolution continuous seismic profile from Lake Zürich, Switzerland. Used to find and identify targets for precision-guided piston coring. Provides an acoustic record for correlation with the sediment record.

mudflow deposits such as 'C' would be completety baffling without this second dimensional control. The hard reflector 'C/B' is a low angle unconformity and lithological change which can be expected in the core at about 6 m subbottom. Our system uses an O.R.E. 3.5 kHz, 10 kW Profiler, with transciever, pulse generator and an EPC 1600s graphic recorder.

Raft

The coring system can be deployed from a number of different types of vessels providing they have lift or boom capabilities for a pull of about 1500–2000 kg. We designed our own ideal raft system for perialpine lakes based on a 5 m × 8 m raft with flat aluminum sealed floats and a tripod over a moon pool. A slit along the center allows easy manipulation of the core barrel. This raft system is highly modular and can be dissambled in a matter of a few hours for easy transport on a modest flatbed truck or trailer.

The tripod has three pulleys. One for the main cable, and one as a helping rope to lift the core barrel using the winch capstan. The third is an all purpose aid and to lower the messenger for deployment.

In figure 9, researchers are using a manual gear crank to gently lift the 350 kg weight stand high enough to insert the core barrel which is hanging from a hairpin through lower flange holes. Head and barrel are attached by two 20 mm cotter pins. The trip weight corer is then loaded and lowered from the trigger lever to counterbalance the piston corer weight.

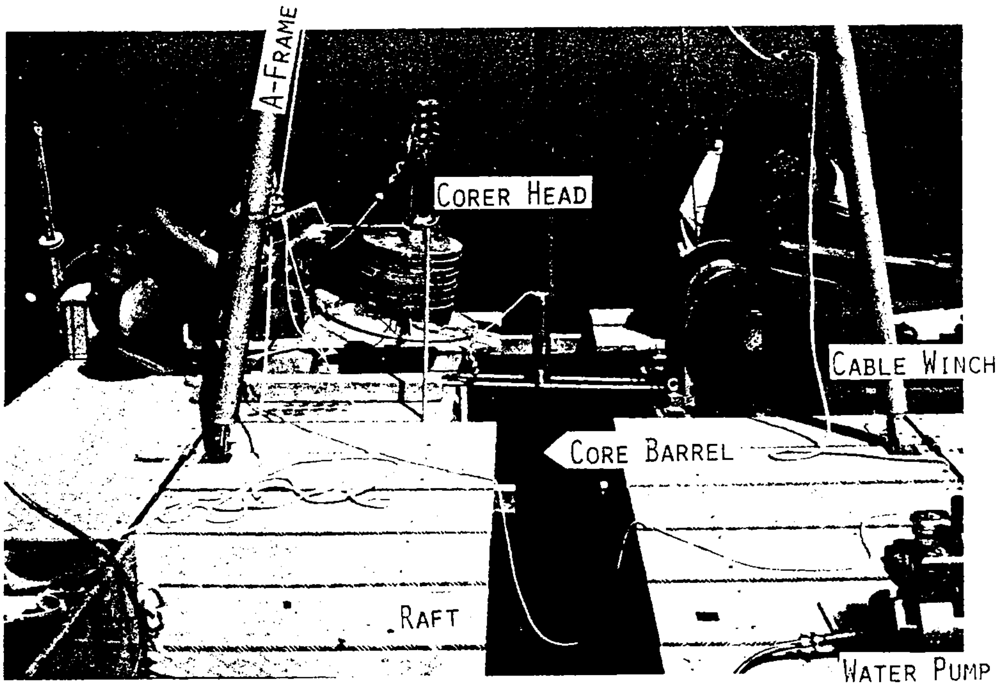

Figure 9. Coring operations from a portable aluminium raft with 6-m A-frame.

Our deep-lake winch is based on an alpine cable lift, comprising a 15 hp motor, leather belt clutch, a 4 speed Fiat-gear box with reverse, dual brake systems, manual gear, disengeable marine capstan, and directly wound cable drum with up to 800 m of 7 or 8 mm cable.

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