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TECHNICAL REPORT

A high-resolution sampler of surface peat

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Abstract. The sampler extracts uncompressed cores of 20-cm diameter, 50–70 cm long from the surface layers of peat. Peat water remains undisturbed in the cores and fugitive variables such as E_H are also retained. Slices as thin as 1 cm can be made with ease. Cores can be got from pools and hollows as well as from lawns and hummocks.

Key-words: Peat, sampler, high-resolution, contained water, redox potential

Introduction

Processes in the acrotelm — the unsaturated, oxygenated top 20 cm or so of a peat bog — and in the immediately underlying saturated anoxic catotelm are of crucial importance in the ecological, hydraulic and chemical behaviour of the whole peat-forming system (Damman, 1978; Ingram, 1983; Clymo, 1983, 1984). The position of the water table and the rapid transition to anoxic conditions are associated with profound chemical changes. In order to elucidate these changes it has become necessary to collect cores with the water retained in position. The record of industrialization may be preserved in this region too (Livett, Lee & Tallis, 1979; Norton, 1985; Clymo & Oldfield, unpublished). In order to study changes in this region (covering a time period of 50–500 y profiles of the rise and fall of measured variables are needed. A single egregious sample in such a profile is of dubious value at best: several contiguous high or low values are needed to establish a significant 'event'. This requires sampling at intervals of 1 cm or less. Sampling at this resolution for pollen analysis is common but is usually in saturated humified peat from the catotelm in which the dry bulk density is typically 0·1 g cm^{-3}. In the acrotelm the peat is loose and its dry bulk density is often only 10% of that in the catotelm, as Fig. 1 shows. In order to get sufficient material from the acrotelm for several sorts of chemical analysis one must use either thick samples, with consequent loss of resolution, or samples of large cross sectional area. Hitherto in such work, samples of 3–10 cm thickness have been used. The results indicate the need for samples no more than 1 cm thick. The peat must, of course, be uncompressed.

In 1968 Dr. B.R. Giles and I began to experiment with peat samplers. The first version of the one described here was made in 1971. It has been much used and modified (usually simplified). The present version works satisfactorily in all types of peat.

Design criteria

The cores must: (1) be uncompressed, (2) retain their water *in situ,* (3) be transportable to a laboratory without damage, (4) be cuttable into 1-cm thick slices. (5) The slices should contain 10 g dry mass. (6) If necessary, one person should be able to operate the corer and to carry it and two or three cores.

Corers of rectangular cross-section have been used in lake sediments (Digerfeldt, 1966) and in peat (e.g. Fenton, 1980). They cannot rotate, so cannot cut wood or *Eriophorum* remains, and their sliding fourth side cannot be sealed. A cylinder can cut by rotation and can be sealed with O-rings, so a cylinder was chosen. Cylindrical piston corers have been used for surface cores (Korpijaako, 1981) but are cumbersome and cause compression (Tolonen & Ijas, 1982). They are ineffective if the surface layers contain gas. A simple cylinder sampler open at both ends was chosen and attention given to how to recover cores without loss of contained water.

Friction between the corer wall and peat tends to cause compression or expansion. The area/perimeter quotient (=diameter/4) should be as big as possible. Experiment showed that quotient values of 3 cm (diameter = 12 cm) or more are satisfactory. Weight imposes a limit of about 20 cm diameter: equipment and three cores weigh about 35–45 kg. For this diameter a 1-cm thick slice of humified peat of dry bulk density 0·1 g cm^{-3} yields 30 g. The uncompressed peat at the acrotelm surface typically yields 7–10 g in a 1-cm slice.

Construction and operation

The essence of the process is as follows. A cylindrical cut is made in the peat. The enclosed mass of peat is then isolated in a PVC sample tube pushed into the cut. The tube is extracted, capped and taken to the laboratory. There it is cut into horizontal slices. The entire sampling apparatus is shown in Fig. 1a.

Cutter cylinder

The cutter is 20 cm diameter, 75 cm long. It has sinuous teeth at the bottom end and a removable transverse steel rod at the top (Fig. 1g, b). The teeth were cut in 1–1·5 mm stainless steel sheet which was then rolled and welded. The teeth were sharpened (and resharpened in the field if necessary) with a half-round file. Tooth tip and notch are arcs of 2·5-cm diameter circles. This allows them to cut where the commoner sharp-pointed teeth stick into woody fragments or trap them in the 'V' notch, displacing them in both cases. The exact dimensions used may not be the best in all circumstances but seem to be satisfactory and better than angular designs as Juusela, Kaunisto & Mustonen (1970) and Helenlund, Lindqvist & Sundman (1972) discovered independently.

In use the cylinder is placed upright on the chosen place. A sharp 30-cm long knife blade is used vertically to cut roots and rhizomes around the circumference. The cutter cylinder is pushed down, raised a little, rotated a little, pushed down further and so on until the required depth is reached. The cylinder is removed and an open ended PVC sample tube is pushed down smoothly and steadily in its place. If there is compression at the surface it can be seen and the core rejected. In practice compression is rare.

Sample tube and attachments

Nominal 8-inch grey PVC pipe (Fig. 1h) was cut to suitable lengths (60 cm was standard) and fitted with flat end caps of the same material. Each end cap was made from a disc of diameter slightly greater than that of the outside diameter of the tube.

The edge of the disc was partly recessed to be a tight fit in the sample tube (Fig. 1c, rightmost item) but the projecting edge which was left makes it easy to knock the caps off when required. They are held during transit by tape. A more water-tight seal can be made with the plug shown in Fig. 1c, centre. This is constructed of two flat PVC discs which are a loose fit inside the PVC pipe; between them is a toroidal rubber O-ring in a recessed groove. Six equidistant bolts connect the two discs. When the bolts are tightened the O-ring is compressed and makes a watertight seal with the inside of the pipe.

The 'nominal 8-inch' pipe has been made steadily smaller and thinner by the manufacturers during the last 15 years. Sample tubes, plugs and caps should be made in batches as batches will probably not be interchangeable.

Extracting the sample tube

In hummock and lawn sites a device to close the lower end of the sample tube and to extract it is needed. This is referred to here as the extractor. In hollows and pools where the acrotelm peat is very fluid a top plug is needed too.

The extractor is shown in Fig. 1d, e, f, h, i. It is operated with two rods made of channel-section aluminium alloy. A circular sharp-edged steel plate of diameter (21 cm) rather more than the sample tube was bent to an arc of radius about 60 cm. One side was attached by a hinge to a rod made of a length of channel-section aluminium alloy so that when the plate is folded up, the convex side lies next to the rod (Fig. 1h). The aluminium wedge beneath the hinge (Fig. 1e) is necessary to relieve strain on the hinge when the plate is pushed down into the peat. Two wires are attached on the opposite side of the plate (Fig. 1d) and run through a hole and over steel rollers (Fig. 1f) in a second, shorter rod, which is also made of channel-section aluminium alloy. The free ends of the wires are attached to a small rectangular aluminium plate with a hole in it (Fig. 1d). This in turn is attached by nylon cord to a handle (Fig. 1d, h).

In use the PVC tube is pushed down first. Then the hinge of the extractor is closed and the circular plate is pushed down beside the top of the open sample tube in a vertical position as shown in Fig. 1h. (The operator would, in reality, be standing level with the top of the sample tube.) As the top of the plate submerges the two wires are taken round the outside of the sample tube. By holding together the loose handle on the end of the wires and a cross bar on the short alloy rod, the wires are kept taut. Both short and long alloy rods are pushed down with cross handles level with each other (more so than appears in Fig. 1h). When the cross handles are level with the top of the sample tube the top of the circular plate and the wires are clear of the bottom of the tube. The plants and peat just around the top of the PVC sample tube are now cleared to a

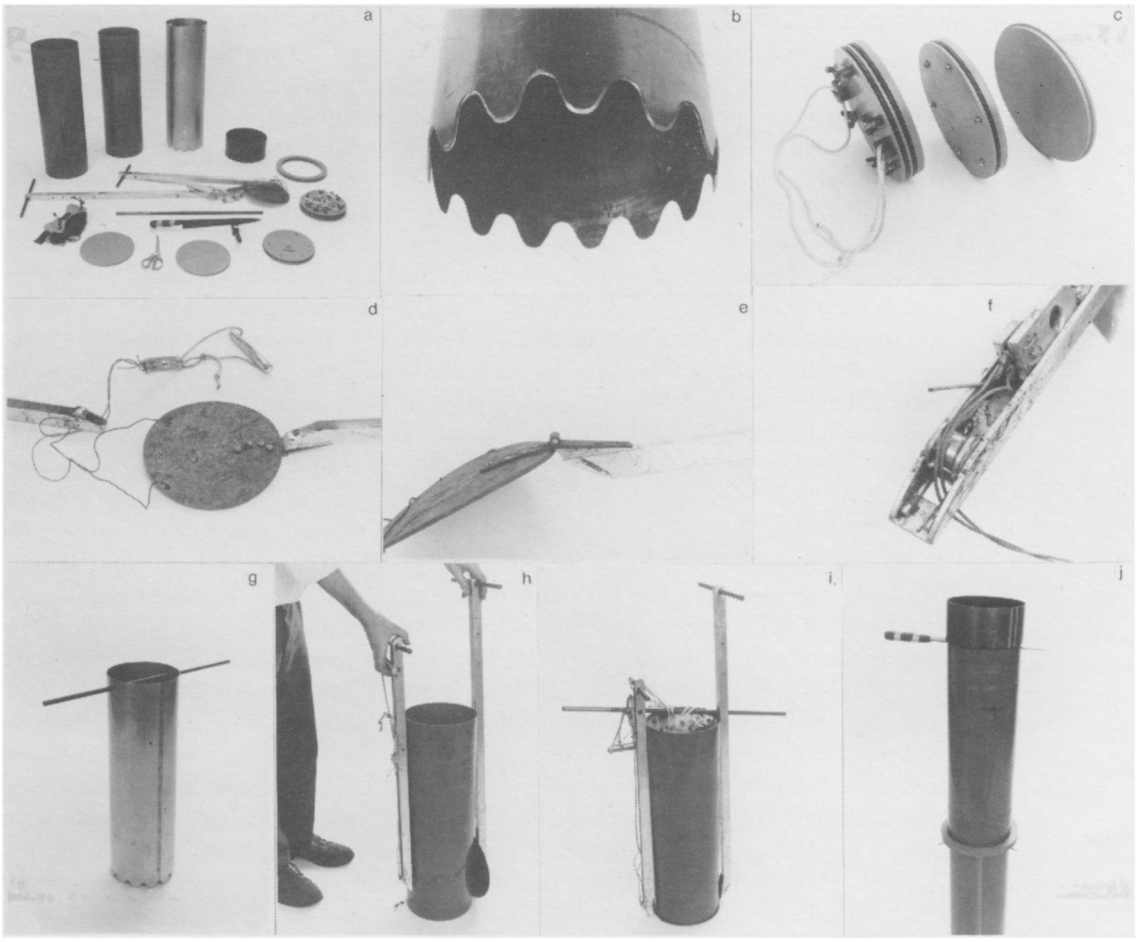

Fig. 1. The apparatus. (a) The three vertical cylinders are (from the left) a sample tube, the pedestal with taper pins, the cutter; in sequence clockwise are the extension tube and locking tube, the pedestal collar, the top-plug, a bottom plug, two sample tube end caps separated by scissors and the gas-cylinder clamp. The central items are the tube closing device ('extractor'), steel cross bar, knife and sharpener. (b) Cutter cylinder teeth. (c) From the left, top-plug (used when the water table is at or above the surface of the peat), bottom sliding plug, end cap. (d)–(f) Tube closing and extracting device details. (g) Cutter cylinder. (h) Tube extractor in use. (i) Sample ready to be drawn up (the strap would be near the top of the tube). (j) Sample tube resting on a collar round the pedestal topped by the extension tube and its locking tube. Two of the three taper pins are visible.

few centimetres depth so that the shorter rod can be strapped to the top of the sample tube (the strap from a gas-cylinder clamp is suitable). The loose handle and the longer rod are then raised simultaneously. The circular plate moves up in an arc (convex side uppermost) across the base of the sample tube and seals it sufficiently well for the immediate purpose. The strap is now looped round both rods and tightened and the metal bar used as a handle for the cutter tube is pushed through holes in the two channel-section alloy rods and through that in the smaller rectangular plate attached to the wires (Fig. 1i). The sample tube, sample and extractor can now be pulled out as a single unit.

In hollows and pools in which the water table is at or above the peat surface a supplementary plug in the top of the sample must be used. This plug is similar to that already described but comprises three discs and two O-rings (Fig. 1c, left). It has a central hole and nylon cord attached to two blocks on the upper side of the plug. In use the plug is pushed gently down inside the sample tube until water wells up through the hole. The hole is then stoppered, the bolts tightened and the cord tied tightly over the inserted metal crossbar (Fig. 1i) so that the plug cannot slip down. Because water is practically inextensible the force on the disc closing the bottom is now much reduced.

The extracted core is immediately put into a

dustbin about ⅔ filled with bog-water. The core weight is thus supported and when the water table outside the tube is made the same as that inside there is no hydraulic potential difference to cause water to leave or enter the core. The extractor and retaining plate are removed, a lower plug inserted, if required, and the end caps fitted. The sample tube and core are lifted out, the tube is dried, and the caps taped on. Masking tape is suitable for the first layer; PVC tape will do for later layers but is too stiff at field temperatures to make a good seal.

The depth of the water table in the hole is recorded after 1 h or so and can be compared with that inferred later in the peat slices.

Cutting slices

Cores are transported upright to a laboratory. While in vehicles they are stood on rubber or compressible foam blocks in buckets to minimize compression from jolting. The cores are stored at 4 °C. When a core is to be sliced it is put into the same dustbin as before but with distilled water sufficient to allow it to float and thus to reduce the hydraulic potential difference between the inside and the outside of the tube to a small value. The bottom cap is then knocked off and, if not already in place, a bottom plug is quickly fitted inside the tube. The tube is lifted out and the bolts in the plug adjusted so that the plug can slide and seal. (Wet humified peat is a good lubricant).

The tube is now put on a cylindrical pedestal of diameter just less than that of the sample tube and tethered to a bench with a gas-cylinder clamp. The cylindrical pedestal is made of similar PVC tube which has been cut lengthways, a thin section removed and the cut edges plastic-welded together again. The pedestal has end caps and three equidistant vertical rows of 1·5-mm holes spaced 1 cm (or any other chosen distance) apart vertically. Before the sample is put on the pedestal, taper pins are put into the three top holes, at the same height, and a PVC collar rested on them. The sample tube is now drawn down smartly around the peat core and slides over the plug until it rests on the collar. The taper pins and collar are moved down and the sample tube drawn down again and so on until the peat core surface is just level with the top of the sample tubes.

A 5-cm extension tube is put on top of the sample tube and held in position with a 10-cm outer locking tube made by welding in an extra piece of tube (Fig. 1j, top right). The taper pins are lowered and the sample tube pushed down thus leaving a 1-cm length of core in the extension.

The locking tube is raised and a long knife is used to cut across the core using the gap between the sample tube and extension tube as a guide (Fig. 1j). The slice or pieces retained in the extension tube are removed. The whole process is then repeated. For surface samples it is usually necessary to use long scissors rather than the knife because there is insufficient resistance for the knife to cut properly. Remains of *Eriophorum* may require scissors too.

It is useful to record fugitive variables such as colour (Munsell scale), E_H and pH. They must be measured on a freshly cut surface because colour and E_H may change dramatically in as little as 5 min. The place where E_H and pH are recorded cannot later be used for measurement of K^+ concentration.

The top of pool cores cannot be segmented in this way because the peat is too sloppy. Such cores must be deep-frozen still upright, which may take several days, then ejected horizontally using the pedestal as a piston. Slices are sawn with a panel saw or a band saw. (Owners of band saws may be loth to co-operate more than once.)

The sample tube is supported in 'V' blocks. It is rarely necessary to cut more than about 20 cm in this way and the remainder of the core, after unfreezing, can be treated as normal. Three complications arise in such cases; frozen peat occupies a volume about 12% greater than unfrozen peat; fugitive variables cannot be measured in the frozen slices; and the dry mass in each slice is unusually small.

With these techniques errors in thickness are not cumulative because all distances are, in effect, measured from the base of the core.

Illustrative results

Four sets of results illustrate the accuracy and usefulness of 1-cm resolution in surface-peat profiles spanning the acrotelm and the top of the underlying catotelm.

Structural properties

Fig. 2a shows the dry bulk density at 1-cm intervals. The calculation assumes that the slice is exactly 1·0 cm thick. The scatter on this curve probably reflects, in the main part, inaccuracy in cutting slices. The results in Fig. 2b indicate this too. The volume of liquid is calculated as (fresh mass – dry mass). The volume of solid is got from the dry mass and the intrinsic density of the dry

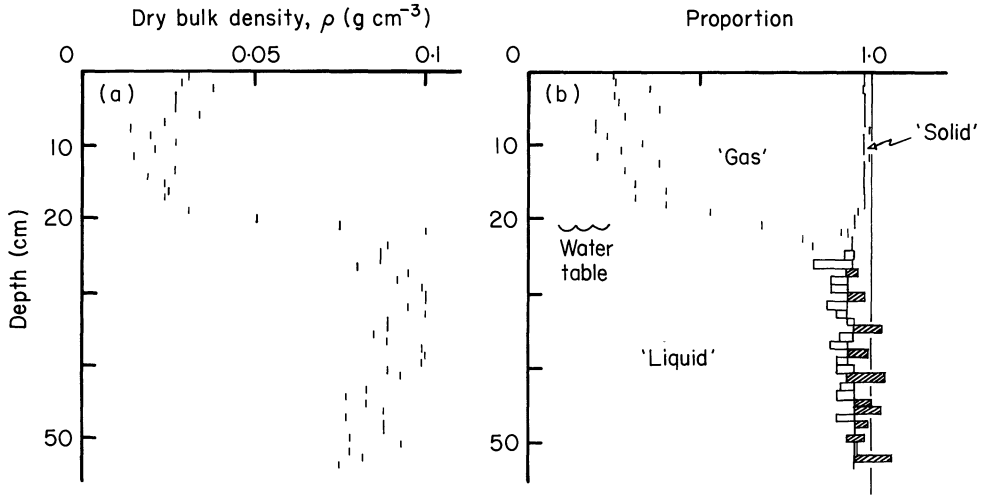

Fig. 2. Core from a *Sphagnum capillifolium* (Ehrh.) Hedw. hummock on Ellergower Moss, Galloway (National Grid reference: NX 480795). (a) Dry bulk density. (b) 'Liquid', 'gas' and 'solid' proportions. Let V_c = calculated volume of the slice, ρ_w = density of water, ρ_d = intrinsic density of dry matter (1·5 g cm^{-3}), M_f = fresh mass of whole slice, M_d = dry mass of whole slice. Then 'liquid' = $(M_f - M_d)/(\rho_w V_c)$; 'solid' = $1 - M_d/(\rho_d V_c)$; and 'gas' is the difference. Below 24 cm, where the peat is waterlogged apparent negative proportions of gas are shown by filled bars and apparent positive proportions by unfilled bars. However, in most places vertical bars representing the value are deliberately left unlinked by horizontal lines because the visual impression could be misleadingly dominated by variations rather than trend. This rather obvious point seems to be rarely recognized.

matter. Both are divided by the *calculated* volume, assuming the slice is exactly 1·0 cm thick. Below the water table there is no gas so the proportions of solid and liquid should add to 1·0. In the lower half of Fig. 2b the total sometimes exceeds 1·0 (filled bars) and is sometimes less than 1·0 (unfilled bars). The mean is 0·002, the standard error (n = 27) is 0·011 and the coefficient of variation is 6%. These translate to mean inaccuracy in cutting of 0·6 mm.

Heat of combustion

The results in Fig. 3a indicate fairly clearly that the energy density in *Sphagnum magellanicum* Brid.

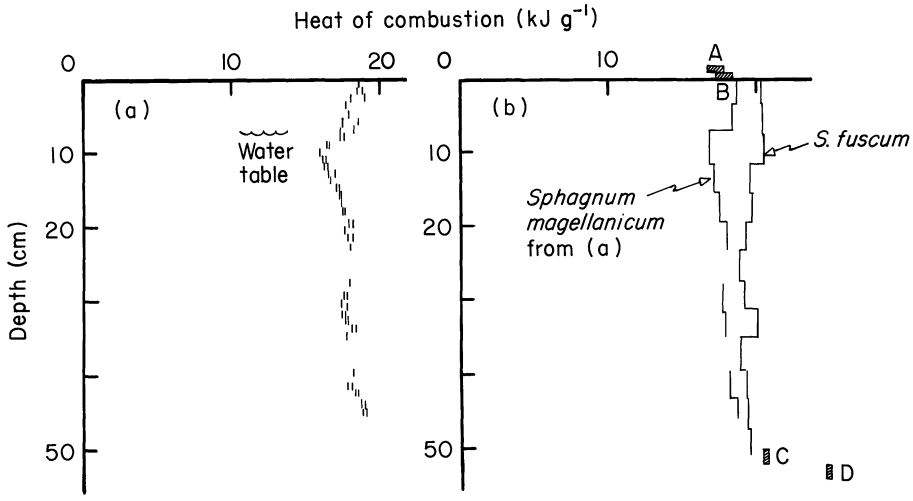

Fig. 3. Heat of combustion. (a) A core from a *Sphagnum magellanicum* Brid. lawn on Cranesmoor, New Forest (National Grid reference: SU 185029). (b) The same data averaged over 4 cm and compared with results from a *Sphagnum fuscum* (Schimp.) Klinggr. hummock at Sunbiggin Tarn, Westmorland (Bellamy & Rieley, 1967). The blocks A-D are ranges: A = *Sphagnum* (Gorham & Sanger, 1967); B = *S. capillifolium, S. papillosum* Lindb., *S. recurvum* P. Beauv., *S. cuspidatum* Hoffm. (Ford, in Clymo 1970); C = 'peat' (Kamula, 1968; Duane, O'Brien & Treacey, 1968); D = Coal.

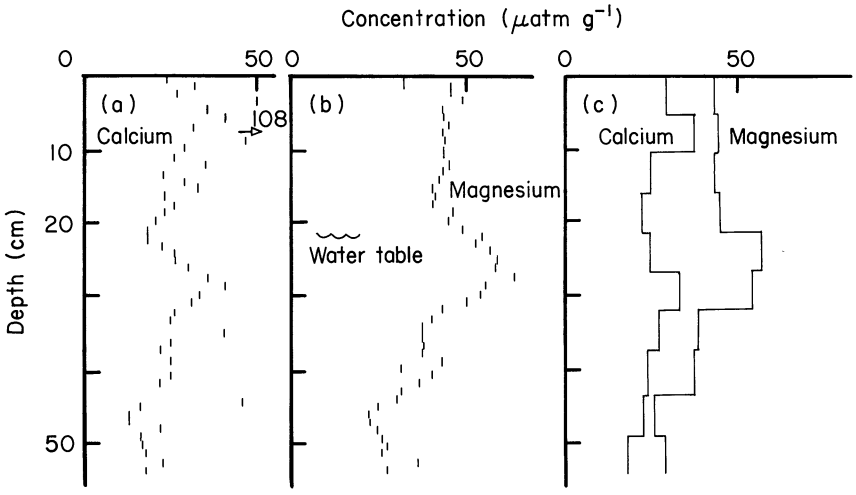

Fig. 4. Concentration of calcium and magnesium in the same core as shown in Fig. 2. (a) Calcium. (b) Magnesium. (c) Same data for both elements averaged over 5 cm.

plants and peat drops initially by about 20% but once submerged the value gradually increases.

When the same data are averaged over 4-cm intervals in Fig. 3b this conclusion is much less convincing. For *S. fuscum* (Schimp.) Klinggr, which is a hummock species, the amplitude of the decline is similar but is spread over 50 cm. The authors of the *S. fuscum* measurements made no comment about them.

Concentration of calcium and magnesium

In Fig. 4a, b are shown results for 1-cm slices; in Fig. 4c the data are averaged over 5-cm slices. The pattern in Fig. 4c is not particularly clear but in 1-cm slices quite noticeable differences emerge. The range of values is larger of course. Above the water table magnesium is generally less variable than calcium. Calcium shows occasional erratic high values. Both show fairly conspicuous undulations, but these are not well synchronised. For example the trough in calcium concentration at the water table coincides with the middle of a section of increasing magnesium concentration. These phenomena will be discussed elsewhere; the immediate point is that they are visible only when 1-cm (or thinner) slices are made.

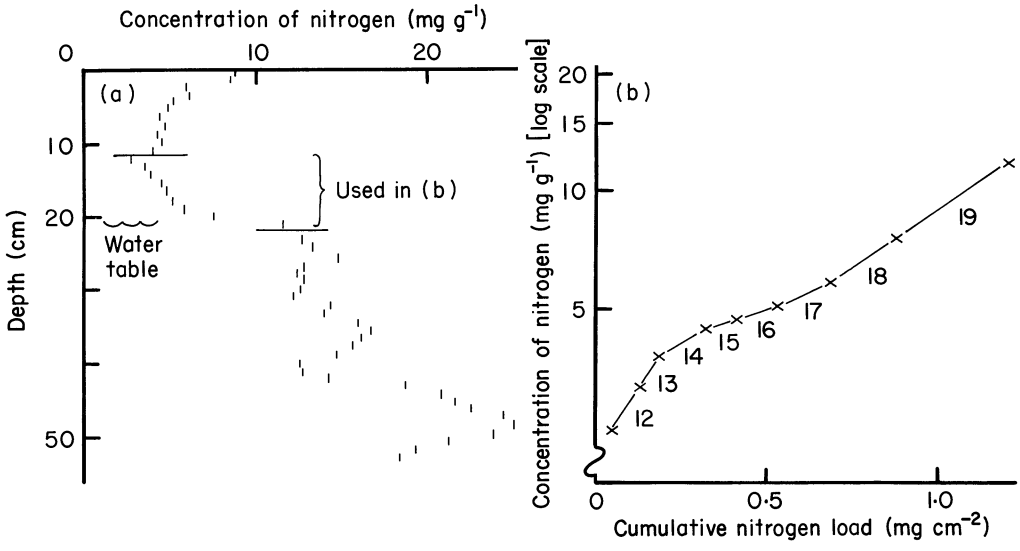

Fig. 5. (a) Concentration of nitrogen in the same core as shown in Fig. 2 (b) Plot to test the hypothesis that nitrogen is conserved. See text for details.

Concentration of nitrogen

In Fig. 5a can be seen oscillations similar to those in Fig. 4. Some of these results can be used in another way. Malmer & Wallén (personal communication) suggest that in some circumstances nitrogen may be conserved during decay in which case its concentration might be used to indicate age. One would expect that a plot of nitrogen concentration on a log scale against cumulative nitrogen, on an area basis, would be a straight line.

For the top 11 cm of the core shown in Fig. 5 the hypothesis is not true because the concentration of nitrogen decreases. Below the water table, where one might expect different microbiological processes to operate, there are obvious complications. But in the range 11-20 cm it seems fair to apply the test, shown in Fig. 5b. Again it is only because measurements have been made at 1-cm intervals that this is possible, and in this case it is only a small part of the profile, not identifiable in advance, which can be used for the test.

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