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GEOMORPHIC, SEDIMENTOLOGIC AND CLIMATIC IMPLICATIONS OF INORGANIC HORIZONS IN RITTERBUSH POND, VERMONT

A Proposal Presented

by

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to

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ABSTRACT

Lake sediment cores from Ritterbush Pond (Eden, VT), recently analyzed in conjunction with pollen research (Lin, 1996), show distinct variations over the last 12,000 ^{14}C years in organic carbon content as approximated by loss-on-ignition (LOI). Numerous horizons of laminated, inorganic sediment (clay and silt) are visually identifiable within a pair of overlapping cores comprised primarily of gytja. Fourteen ^{14}C dates indicate that several inorganic horizons were deposited in relatively short time intervals. The dates suggest that such horizons represent depositional events, such as hillslope denudation caused by a period of increased rainfall, which has implications for climate change during the Holocene. I propose to determine the spatial distribution of these inorganic horizons, to investigate their physical stratigraphy, to explore geomorphic reasons for their origin, and to infer sedimentologic mechanisms for their deposition.

Introduction

Ritterbush Pond is located in the Town of Eden, Lamoille County, Vermont (Figure 1). It was recently cored in conjunction with pollen and stable isotope research of Holocene (<12 ka) sediments (Lin, 1996; Lini et al, 1995). The pair of overlapping cores (a total of 5.75 meters) show distinct variations in organic carbon content as approximated by loss-on-ignition (LOI) (Figure 2). Numerous horizons of laminated, inorganic sediment (clay and silt) are visually identifiable within the gytja, organic sediment that is gradually deposited as a result of the primary productivity of organisms living in and around the lake. Fourteen ^{14}C dates have been obtained for one core (RT-2), and six of those dates bracket three of the inorganic horizons. The dates indicate that the horizons were deposited rapidly (Figure 3), suggesting that such horizons represent discrete depositional events, such as hillslope denudation caused by a period of increased rainfall, which may have implications for climate change during the Holocene.

Background

Pollen Anaylsis

Traditional lake core analysis in New England has focused on the pollen records found in the Holocene organic material contained within lake basins as a proxy for climate change and vegetation cover. The transition from the Wisconsinan glaciation to the present interglacial stage has been documented using the change in pollen spectra over time, which reflects the expansion of tree species northward as the ice sheet receded. The Younger Dryas stade, a return to cooler climate conditions between 11,000 and 10,000 ^{14}C yr B.P., has a recognizable pollen signal (Davis and Jacobson, 1985), and is accompanied by an increase in inorganic sediment due to decreased productivity and in some regions proximity of the ice sheet (Thompson et al, 1996). With the exception of research on the Younger Dryas, the significance of inorganic material found within the lacustrine stratigraphies of New England has been largely ignored.

Ritterbush Pond

Previous Work

Ritterbush Pond has been studied only in regard to the existence of mountain glaciers in New England. Wagner (1970) investigated Ritterbush Pond and Lake Mansfield as possible cirque basins, and identified morainal features in the surrounding areas. This interpretation was quickly disputed (Stewart, 1971; Connally, 1971), but remained unresolved as the existence or absence of mountain glaciers could not be proven conclusively. Sperling (1989) re-examined Wagner's work and interpreted a basal radiocarbon age of 10.7 ka from Ritterbush Pond as the age of deglaciation. Current accepted theory holds that mountain glaciers did not exist in either the White or Green Mountains at the close of the Wisconsinan (Thompson et al., 1996). Sperling (1989) does provide data useful to this study including a dated core with stratigraphic description, and pollen analysis for Ritterbush Pond.

Recent investigations at Ritterbush Pond include a detailed pollen chronology and deglacial climate and vegetation history (Lin, 1996). Li identified the inorganic peaks visually and by their low LOI values, and hypothesized that they were due to sediment resuspension or flood events. Her climate reconstruction does not address the climatic implications of the horizons.

Proposed Research

This investigation is possible due to the unusual characteristics of the basin and the sediment record, most notably, the steepness of the slopes surrounding the pond (Figure 1). Steep slopes have a greater chance of failure and higher rates of erosion than gentle slopes composed of similar material. Samples of gytja above and below three of the inorganic horizons have been ^{14}C-

dated to constrain their ages. In each case, the dates bracketing the horizon fall within two sigma, but are inverted; the date at the top of the horizon is older than the date below (Figure 3). This suggests that there has been scouring and redeposition of older sediment. These ^{14}C dates are consistent with a rapid influx of inorganic material into the basin, possibly carried into the basin by turbidity currents, due to increased rates of hillslope erosion.

The upper and lower contacts between the inorganic horizons and the gytja vary from sharp to gradational, indicating that more than one mechanism may be depositing the inorganic layers. The most likely mechanisms, turbidite sedimentation and subsequent suspension settling, and transport of material from the lake margin to the center of the basin (sediment focusing), should be distinguishable by comparison of micro-stratigraphy and spatial distribution of the horizons. The inorganic layers that have terrestrial or fluvial sources should be relatively continuous and thicken shoreward in the direction of the sediment source, deltas and alluvial fans at the lake margin. Reworked sediments may be discontinuous. By tracing the inorganic horizons to their source and by constraining ages, I will document the source, timing and distribution of sedimentation events as recorded in the basin.

Sedimentation events are most likely due to increased stream sediment load or mass wasting of surrounding hillslopes. Another possible mechanism for their deposition is a decrease in lake primary productivity due to a period of cooler temperatures. In the latter case, the inorganic layers would represent long periods of time, contrary to the ages reported by the ^{14}C dates. If the layers are due to increased hillslope erosion rates, they may be triggered by a period of increased rainfall, or a loss of vegetative cover due to fires. To determine if sedimentation was initiated by a fire, the horizons will be analyzed for charcoal content and abundance (Meyers et al, 1995; Winkler, 1985).

<u>Stable Carbon Isotopes</u>

Lini et al. (1995) used stable carbon isotope analysis to investigate terrestrial vs. lacustrine sources for the carbon in the Ritterbush Pond cores. He determined that the source for the carbon changed over time, and that the inorganic layers had isotopic values indicative of terrestrial carbon organic material. I plan to use stable carbon isotopes to determine the source of the carbon found in the inorganic horizons and the gytja surrounding them (Lini et al., 1995).

Loss-on-Ignition (LOI)

Extensive paleoclimate proxy data (pollen analyses) have been recovered from the ponds and bogs of New England, resulting in a regional, deglacial, vegetative chronology (Davis and Jacobson, 1985; Anderson et al, 1992; Spear, 1989). A traditional analytical tool for the estimation of organic carbon content is loss-on-ignition (LOI). Numerous lake core studies have published LOI records (Thompson et al,1996; Anderson et al, 1992; Peteet et al, 1990; Spear, 1989; Winkler 1985a) but none are continuous nor have they been performed at the detailed scale I propose to use (1 cm intervals). Therefore, it is difficult to use existing LOI records to identify the timing and distribution of inorganic horizons in other lakes.

Sediment focusing

Sediment focusing is defined as the movement of sediment to the deepest part of the basin (Lehman, 1975). Focusing results in non-uniform deposition of sediment on the lake floor. Sediment focusing is a direct result of basin morphometry and the processes that act to redistribute sediment, such as water currents, overturning and seiches, turbidity and density currents, and underwater slope failure. Several studies of New England lakes have shown that sediment accumulates faster in the center of the basin than on the shallower margin (Davis and Ford, 1982; Davis, 1968). This phenomenon makes it difficult to unravel the sedimentological history of the lake, as sediments that were initially deposited in continuous and horizontal layers may not longer be traceable.

Hilton (1985) provides a conceptual model for understanding sediment focusing. He considers four processes to most likely influence focusing in small lakes; 1) sliding and slumping of sediment laden slopes, 2) intermittent complete mixing of the water column, 3) peripheral wave action, and 4) random redistribution of sediment due to wave activity at the lake margin. The effect of these processes on sediment stratigraphy is not specifically addressed. Due to the irregular basin morphometry (Figure 4), and the deep sediment found in Ritterbush (Figure 5) it seems prudent to include this mechanisms in a consideration of lake sedimentation. Hilton also acknowledges that it is not yet possible to predict the degree to which a lake will experience focusing.

Turbidites

Turbidites have long been investigated as a mechanisms for producing graded and laminated bedding (Keunen and Migliorini, 1950; Walker, 1967). Piper (1972) used grain size analysis to infer that laminated mudstones were the result of turbidite deposition. He found that the turbidite sequences showed an overall upward decrease in the thickness, abundance, and grain size of laminae and that the contacts between the laminae were usually sharp, but sometimes gradational. Ludlam (1974) investigated the role of turbidity currents in lake sedimentation at Fayetteville Green Lake in central New York and estimated that 50% of the material accumulated on the basin floor was transported by turbidites.

Other Related Research

Investigations of hillslope denudation and lake infilling commonly link increased rainfall or runoff to increased stream sediment loading (Costa, 1975). Although the episodic deposition of non-varved inorganic horizons in lakes has not been directly addressed, recent research links storm events with inorganic horizons in Holocene coastal lake sediments (Liu and Fearn, 1993).

Significance of Research

My research will build upon the existing well-dated pollen chronology for Ritterbush Pond and establish a chronology of inorganic sedimentation events. If it can be shown that these sedimentation events were caused by hillslope denudation due to large-scale storm events, and they can be found in other regional lakes, it may be possible to determine storm frequency for New

England during the Holocene. By defining the spatial and temporal distribution of the inorganic horizons, it will be possible to 1) estimate long-term rates of organic matter accumulation within the lake, 2) estimate average rates of inorganic sedimentation and rates of hillslope denudation for the watershed, 3) identify periods of hillslope instability and 4) use the depositional history of Ritterbush Pond to infer periods of increased rainfall intensity or duration in Northern Vermont during the Holocene.

Plan of Investigation

Field Work

Work to date has included the retrieval of three continuous cores from Ritterbush Pond using a modified Reasoner coring device (Reasoner, 1993). The locations of these cores were selected using bathymetry and isopach maps we (Dave Shaw, Sarah Brown and Paul Bierman) developed this winter from extensive sediment probe data (Figures 4, 5 and 6). Additional field work this spring and summer will map the surficial geology of the basin to identify of the sediment types and sources within the basin. After initial analysis of these cores, it will be determined if more cores from Ritterbush Pond or other lakes are needed.

Core Sampling and Laboratory Analysis

The goal of the core analysis is to use several methods to gain the best understanding of the layers. These procedures will help to identify and correlate the inorganic horizons. In all cores retrieved, magnetic susceptibility will be measured. Magnetic susceptibility is routinely reported in lake core studies, and measures the relative magnetism of the sediments at 3 cm intervals. Inorganic horizons will have a higher magnetic susceptibility than the organic gytja, due to the presence of magnetite in the rocks of the watershed and sediments of the pond. Because the core is encased in PVC pipe, magnetic susceptibility is measured before the core is split. I have borrowed a magnetic susceptibility coil from P.T. Davis of Bentley College, and have built a rack to facilitate processing of the core segments. Measurements will be taken every 3 cm for the length of the core and each core will be run twice to allow for calculation of statistical error.

The cores will then be split lengthwise, photographed, and video logged. I will log visual stratigraphy immediately after splitting, before the sediments oxidize and the fine details are lost. Detailed stratigraphic logs will be prepared. One half of the core will be sampled at 1 cm intervals for further analysis, including LOI, stable carbon isotopes, and possibly, C/N. LOI is an estimate of carbon content, which will help to delineate the boundaries between organic and inorganic horizons. Stable carbon isotope analysis will help to determine the source (terrestrial or aquatic) of the carbon in the inorganic horizons and the surrounding gytja. C/N measures the total carbon and nitrogen in a sample, and can be used to check LOI values.

Selective high resolution sampling will be performed on the inorganic horizons and surrounding gytja. I hope to identify inorganic horizons in core #2 (Figure 6), and trace them to horizons found in cores closer to the lake margin to determine if the horizons are laterally continuous. Layers selected for high resolution analysis will be sampled at 5 mm increments. Because there is already a stable carbon record for Ritterbush (Lini et al., 1995), stable carbon isotope analysis will be used only strategically to help distinguish between terrestrial and aquatic source material in and around the inorganic horizons. Using the Accelerator Mass Spectrometer (AMS) at Lawrence Livermore National Laboratory, I will continue to bracket the depositional events with ^{14}C dates as funding allows.

The stratigraphy of the selected inorganic layers will also be investigated using grain size analysis. I will use a sedigraph (at University of Maine) for detailed grain size analysis across selected horizons. This will determine the degree of grading and lamination within the horizons. Thin sections of the same layers and surrounding gytja will be prepared using the acetone exchange method (Clark, 1988) in order to examine physical stratigraphy and count any charcoal present (Clark, 1988; Winkler, 1985b).

Estimated Timetable

January - March 1997

- -Sediment probing at Ritterbush Pond - COMPLETE
- -Practice core retrieval - COMPLETE
- -Retrieval of 3 cores for analysis - COMPLETE

March - June 1997

- -Lab analysis of cores
- -^{14}C measurements at Lawrence Livermore
- -Surficial mapping of the Ritterbush drainage basin
- -Write abstract for GSA

September - December 1997

- -Continue laboratory analysis
- -Present findings at National GSA meeting in Salt Lake City, Utah
- -Presentation of progress report to the Geology Department
- -Begin thesis writing (methods, previous work, figure creation etc.)
- -Determine if additional cores are necessary

January 1998 - COMPLETION

1) -complete and defend thesis in March/April 1998 **OR**
2) -take and analyze additional Ritterbush cores
   -complete and defend thesis (September 1998) **OR**
3) -take and analyze additional cores from other ponds
   -synthesize data, complete and defend thesis (September 1998)

Funding

The primary expense for this research is the cost of ^{14}C dates from Lawrence Livermore National Laboratory. I have applied for grants from the Vermont Geological Society ($300), Sigma Xi ($600), GSA ($1800), and for the GSA Howard Award ($1200). To date, I have received $300 from VGS toward the dating of cores. It will be possible to complete this thesis without any additional dates, as core RT-2 is already well dated. However, a minimum of six AMS dates ($1800) is desired, although more extensive dating will facilitate the creation of a detailed event chronology.

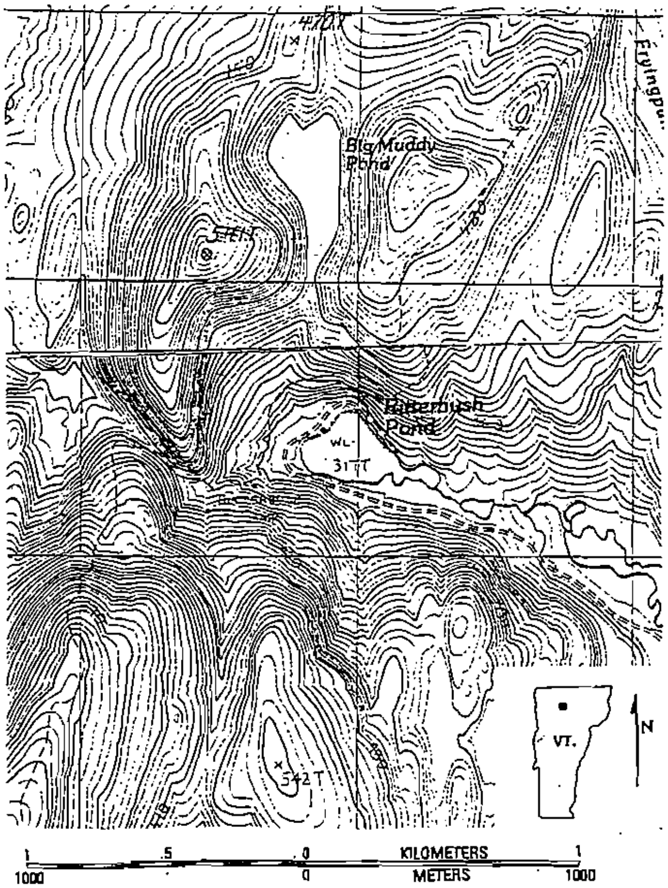


Figure 1: Location of Ritterbush Pond (from Eden and Hazens Notch Quadrangles). Contour interval is 6m.

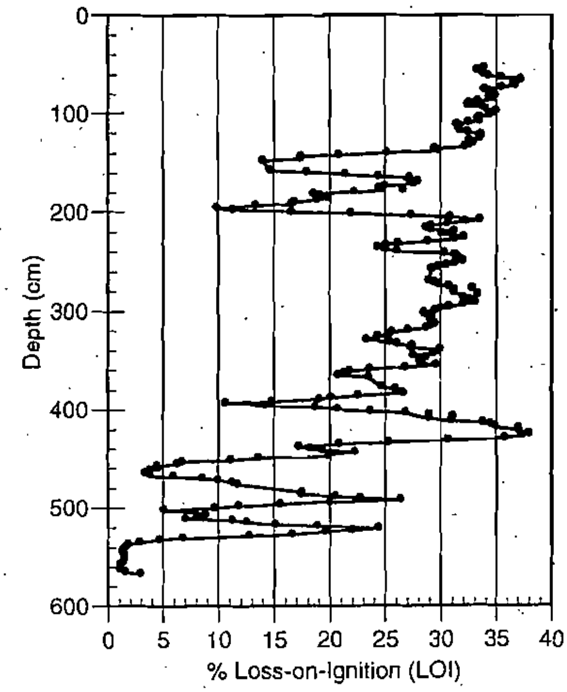


Figure 2: Loss-on-ignition data (five point running average) for RT-2 from Ritterbush Pond. LOI values <15% represent the significant inorganic horizons (after Lin, 1996).

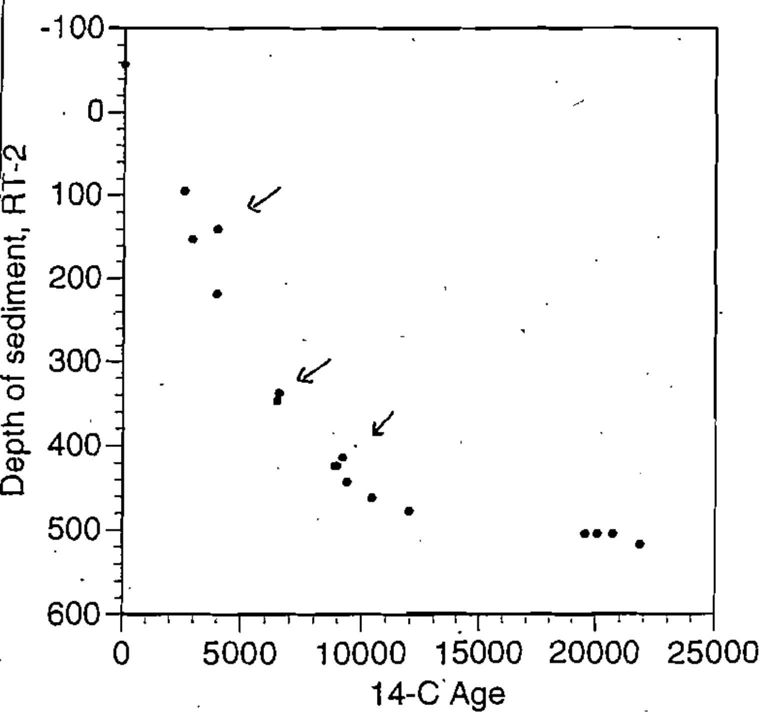


Figure 3: AMS dates for RT-2. Dates bracketing inorganic horizons are indicated with an arrow.

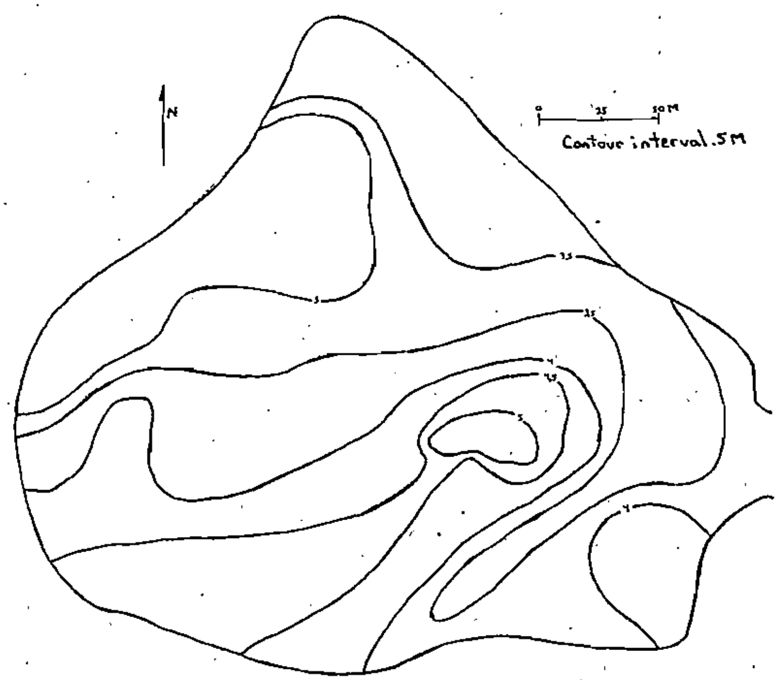
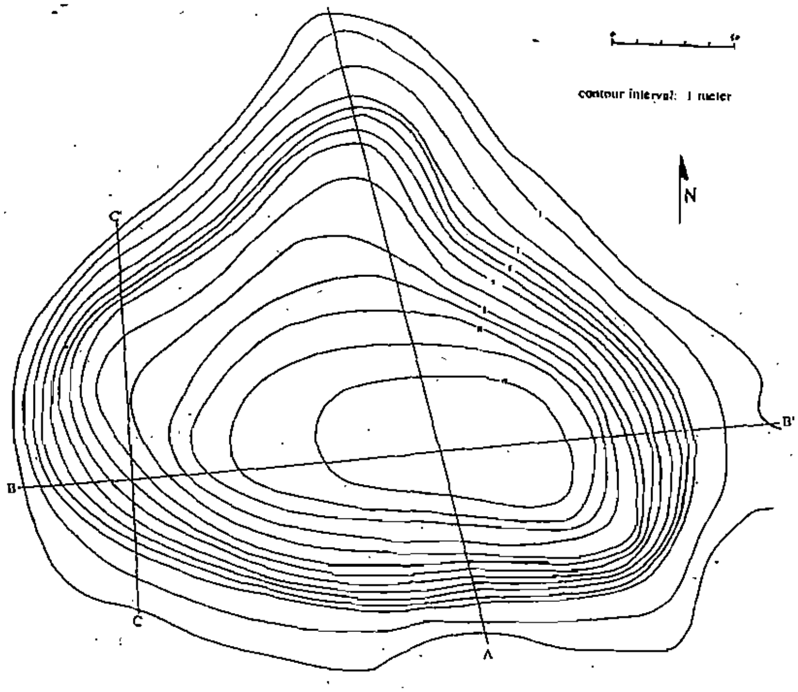


Figure 4: Sediment thickness (meters) in Ritterbush Pond. Data was gathered (Jan 1997) from over 60 sediment probes to refusal. (Contouring by David Shaw)



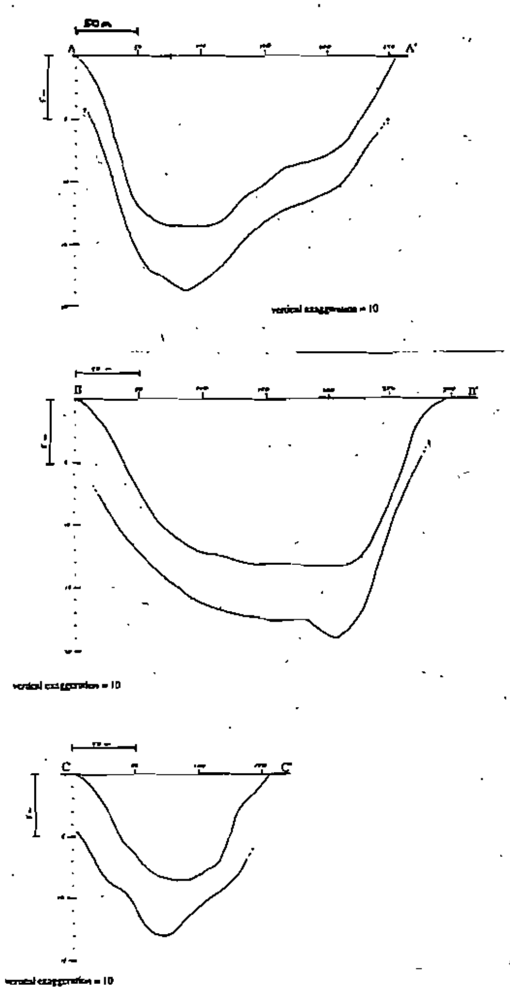


Figure 5: Bathymetry of Ritterbush Pond with cross sections showing sediment thickness and original basin surface. Data was gathered (Jan 1997) from over 60 bathymetric and sediment probes to refusal. (Contouring by David Shaw)

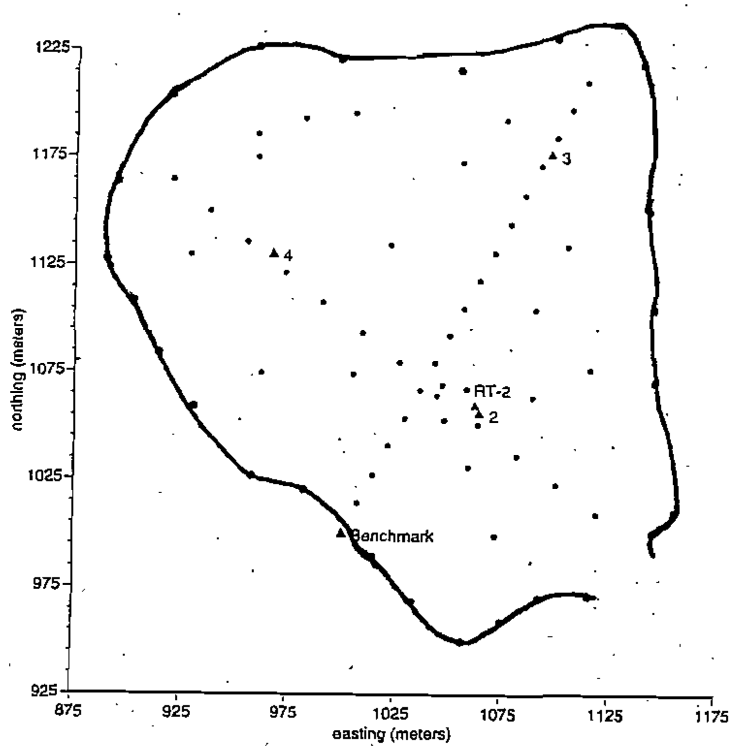


Figure 6: Data collected Jan - March 1997 at Ritterbush Pond. All points surveyed with electronic total station from the Benchmark on the lake perimeter. Bathymetric and sediment probe points are denoted by small dots. Core locationsare marked by triangles. The approximate location of core RT-2 is also noted.

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