RESEARCH REPORT

A PROPOSAL TO MEASURE EUTROPHICATION IN THE POTOMAC RIVER

(A PILOT STUDY)

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I. OBJECTIVES

The Potomac River receives effluent from the Blue Plains Waste Water Treatment Plant and from many other point and non-point sources of pollution. The objectives of the present study are to analyze the combined effects of nutrient loading due to regional land use patterns and to point-source pollution (specifically the Blue Plains plant), and to determine whether or not it is possible to distinguish the effect of the latter source in the sedimentary record. In order to address this question, stratigraphic studies of cores taken at different locations in the river are being carried out; this initial investigation is designed to evaluate the usefulness of the method.

When phytoplankton remains are incorporated into the sediment column, their pigments are partially broken down and preserved as "sedimentary chlorophyll degradation products" (SCDP; see Vallentyne, 1955); SCDP is considered an index of algal biomass. Changes in the vertical pollen profile reflect regional changes in vegetation, and some of the changes can be dated by correlation with historical records. Using dated horizons based on pollen analysis we can calculate sedimentation rates, and with this information we can assign a date to any level in the core. Hence, by using the stratigraphic method, one can trace the history of eutrophication through time, date the horizons where changes are evident, and look for possible causes of those changes in the historical record.

II. METHODS

Equipment and Sampling Methods:

On March 10, 1977, five sediment cores were taken from the Potomac River using a Livingstone piston core with a barrel one meter in length and two inches in diameter. All cores were extruded on the boat, where they were divided into individual samples and placed in plastic sample bags. The samples were then brought back to the laboratory and stored in a refrigerated room.

Site Selection:

The primary concern in selecting core sites was to identify the spots most likely to have an undisturbed stratigraphic sequence in the sediment column. The continuing processes of erosion and deposition in the river channel insure that, even with the most careful selection, the chances for success at any particular site cannot be predicted. The history of dredging and other forms of human interference with the natural channel of the Potomac add further complications to the situation. After consultation with the Army Corps of Engineers and the National Park Service, it was possible to select several locations which were thought to be undisturbed by dredging or urban development. These locations were all in sheltered areas at a reasonable distance from the main channel, so that they were not considered to be subject to extensive disturbance by natural processes. (The only way to test these assumptions, of course, is to analyze the individual cores and to see whether the pollen record reveals a meaningful pattern.)

Another criterion used in site selection was location with respect to the Blue Plains Waste Water Treatment Plant. It was hoped that the increase of algal productivity in response to nutrient input from the plant effluent would follow a geographic pattern that could be recognized in our SCDP profiles. Our cores were taken at increasing intervals downstream from the plant (see fig. 1); the closest one was about two miles south of the plant, as we had been advised that the chances of finding an undisturbed sequence in the area near the plant were very slim. (This was an area where extensive dredging, dumping and naval underwater testing had all taken place.)

The five cores were taken at the following sites (see fig. 1): (#1) offshore from Alexandria, near the outlet of Hunting Creek; (#2) at the mouth of Broad Creek, near Indian Queen Bluff; (#3) offshore from Mason Neck, between Sycamore Point and Hallowing Point; (#4) at the mouth of Little Hunting Creek, near Mt. Vernon; (#5) Piscataway Creek, offshore from Farmington (near the outlet of a small sewage treatment plant which has recently begun operations).

<u>Core Description</u>:

None of the cores were marked by visually obvious horizions, such as color or textural banding; most variations of color and texture that did occur were gradual.

<u>Core #1</u> was composed of brownish grey sandy clay, with a slightly darker color toward the bottom. Samples at the top were considerably sandier than at the bottom. The total length of the core was 77 cm; a break occurred at 15-1/2 cm. from the top of the core (this could have been either a natural break in the core or an artifact of the extrusion process). The top section was less cohesive than the bottom. The bottom 61 cm. was divided into 41 samples (1-1 is at the bottom of the core) while the top section contains samples 42 through 49.

<u>Core #2</u> was composed of dark grey-brown sandy clay. Several artifacts resembling nails were noticed at different levels in the core during extrusion; as this core has not yet been analyzed, no further examination of these objects has been made. The core was 93 cm. long, with a break at 15 cm. from the top. The bottom section (78 cm. long) was divided into samples 2-1 through 2-57, while the top section was divided into samples 2-58 through 2-67.

Core #3 was composed of grey-brown sandy clay. Small leaf fragments were found at all levels of the core. Some samples exhibited dark grey spots when they were cut open to be processed, but these did not follow any kind of pattern; they appeared to be diagenetic rather than depositional features. The length of the core was 98 cm., with breaks at 5 cm. and at 44 cm. from the top. The upper break was due to the looseness of the surface sediment; the lower break may be related to a textural change, as the samples below the break were observed during processing to contain more sand than the samples above the break. Further analysis of the core has not produced any data to indicate that the break was stratigraphically significant. The bottom 54 cm. section was divided into samples 3-1 through 3-41; the next 39 cm. section was divided into samples 3-42 through 3-71; and the top section contained just three samples, 3-72, -73, and -74.

Core #4 was composed of sandy clay which was medium-dark brown at the bottom, gradually changing to light grey-brown in the upper half of the core. The upper samples also seem to be stickier and richer in clay, although this may simply be a result of higher water content. A disarticulated bivalve shell was found at the bottom of the core. The core was 92 cm. long. A break occurred at a depth of 17 cm.; the sediment above the break was relatively unconsolidated. The bottom 75 cm. were cut up into samples 4-1 through 4-73, while the upper samples were numbered 4-74 through 4-81.

Core #5 was composed of greyish-brown sandy clay; the color was homogeneous, but the upper parts of the core seemed to be sandier and richer in organic matter. The length of the core was 93 cm.; samples 5-1 through 5-87 represent the bottom 87 cm., while the top 6 cm. were divided into samples 5-88, -89 and -90.

III. LABORATORY METHODS

Pollen Extraction and Analysis:

Weighed sediment samples were placed in Nalgene 15 cm. centrifuge tubes and treated with a variety of reagents in order to isolate the preserved pollen grains. The process used to extract the pollen from the sediment followed (with minor modifications) the procedure that was used at the Great Lakes Research Division under the direction of Dr. Margaret Davis (see attached photocopy). Processed samples were washed with 95% ethyl alcohol, 100% ethyl alcohol, and tertiary butyl alcohol; they were then placed in sample bottles with a measured volume of tertiary butyl alcohol. Each slide was prepared on a warming plate, using a small drop of silicone oil as a mounting medium; the pollen sample then was thoroughly resuspended in the tertiary butyl alcohol and a measured volume of the suspension placed on the drop of silicone oil. When the tertiary butyl alcohol evaporated a cover slip was placed on the slide.

Pollen analysis of each sample involved examination of the total surface area of at least three slides at a magnification of 400X. All arboreal and herbaceous pollen types which could be recognized were identified and counted; grains which could not be identified due to visual obstruction or distortion of the grain itself were classified as "unidentified"; and grains which were clearly visible but not identifiable were classed as "unknown". Grains which were only tentatively identified with the help of reference materials were marked "cf." on the count sheets, but these uncertainties had a negligible effect on the relative frequencies of the major pollen types.

For every sample counted, a minimum of 200 grains were included in the pollen sum; almost all samples represent a sum of between 250 and 350 grains. All recognized tree and herb pollen types were included in the sum. Spores and aquatic pollen were not included in the sum, although they were identified whenever possible. Relative frequencies of the types represented on the pollen diagrams are expressed as a per cent of the pollen sum as defined above.

In order to obtain "absolute" pollen frequencies, the following data were used: W, weight of the sample; D, dry weight expressed as a per cent of wet weight; V_t, volume of tert-butyl alcohol in suspension; C, concentration of the sample suspension (dry weight of sample/volume of tert-butyl alcohol); V_s, volume of suspension on a given slide; N, number of grains per slide. The following calculation was used:

$$(1) \qquad \frac{WD}{V_t} = C \quad (\text{gm. per ml.})$$

$$(2) \qquad \frac{N}{V_s C} = \text{Number of grains per gm. dry weight of sample}$$

This statistic was calculated for each slide; the absolute pollen density for each sample is expressed on the pollen diagram as a mean value, with a bar extending one standard deviation in either direction (see fig. 2).

"Absolute" pollen density is used in these diagrams only to indicate total concentration of pollen in the sediment; this is because changes in the pollen concentration may be caused by several factors: Changes in the amount of pollen produced by a group of trees, changes in the number of trees producing pollen (e.g. deforestation or old field succession) and changes in the rate of mineral sedimentation must all be considered. The factors affecting the concentration of pollen in any given sample cannot definitively be isolated and evaluated; yet this parameter is valuable because it may suggest trends or corroborate trends suggested by some other data. For example, if a major change in total pollen concentration is not accompanied by a comparable change in relative frequency of individual types, the event can probably be interpreted as a change in the sedimentation rate.

Determination of SCDP:

SCDP, or "sedimentary chlorophyll degradation product," is an indicator of the amount of pigment in the sediment. It does not measure the amount of any single chemical compound; rather it measures the presence of a complex group of stable derivatives of the major photosynthetic pigments. Algal productivity is assumed to be the major source of these pigments in the sediment column. (Leaf litter has generally been at least partially leached of its pigment before it reaches a resting place on the river bottom. A study by Dr. Grace Brush (personal communication) has shown that SCDP in Back River may vary drastically despite a fairly constant amount of leaf litter in the sediment, and thus the influence of leaf litter can be regarded as minimal.)

The method used to extract SCDP from the sediment follows that of Vallentyne (1955). A weighed amount of sediment in a test tube is mixed with 90% acetone. (Vallentyne added 0.5% redistilled dimethylaniline to increase his SCDP values by about 10%, but we have simplified the process by removing this step. All SCDP data presented here are used for comparison of different levels in a core rather than for rigorous quantitative calculations.) The sample is allowed to stand overnight with occasional mixing, and is then filtered through a Whatman filter paper. The extract is collected in a graduated cylinder and its volume is recorded. A sample of the extract is placed in a standard 1 cm. quartz cell and its absorbtivity is measured in a Beckman DU spectrophotometer at a wavelength of 667 mm. (90% acetone is used as the blank in this determination.) The number of SCDP units for a given sample is then calculated as:

$$\frac{(\text{Absorbtivity}) \times (\text{Volume of Extract})\ (\text{ml.})}{(\text{Dry Weight of Sample Extracted})\ (\text{gm.})}$$

For the samples analyzed here, the amount of ignitable matter per gram dry weight of sediment has been measured in order to obtain a measure of SCDP independent of the rate of mineral sedimentation. Each sample was weighed, dried, and weighed again to find the ratio of dry weight to wet weight; the dry sample was then ground in a mortar and pestle, dried again, placed in a crucible and heated to a temperature of 600°C for about an hour. The sample was weighed once more and the decrease in weight divided by the dry weight of the sample to determine the "per cent of ignitable matter". The figure previously derived for SCDP was divided by this number to find "SCDP per gram of ignitable matter".

IV. DATA

To date, two cores (Core #1 and Core #3) have been processed and analyzed. On the attached diagram, total pollen concentration and SCDP/

gram of ignitable matter are plotted vs. depth from the top of the core. In addition, the dominant pollen types (pine, oak, ragweed, grasses) are represented by plots of per cent of pollen sum vs. depth. Two of the less abundant arboreal types (sycamore for Core #1 and hickory for Core #3) are also represented this way to see if they reflect trends found in the other profiles. Finally the ratio of oak/ragweed is plotted against depth. This ratio is a rough measure of changes in the amount of forest cover, because oak is the dominant arboreal pollen producer in both profiles, while ragweed is an agricultural weed which responds rapidly to events of forest clearing.

Several features stand out in these profiles:

(1) In Core #3, between 80 and 60 cm. from the top, we see a sharp decline in oak and hickory pollen, accompanied by a rise in the relative frequency of ragweed pollen. Pine reaches a peak between 65 and 60 cm., followed by a decline. Pollen concentration in the sediment and SCDP/gm. ignitable matter both reach peaks and then decline in the interval between 80 and 60 cm.

(2) Between 30 cm. and 0 cm. depth in Core #3, there is a gradual increase in pine and oak pollen and a corresponding decline in ragweed. Pollen concentration and SCDP also increase in the upper 20 cm. of the core.

(3) In Core #1, the bottom samples contain high amounts of ragweed pollen and relatively low amounts of oak and pine pollen. Between the bottom of the core and about 50 cm., ragweed experiences a gradual decline in relative frequency; while oak increases sharply between about 65 and 55 cm. The increase in oak and decline in ragweed coincide with a peak at about 55 cm. in the SCDP column.

(4) Above about 45 cm. in Core #1, ragweed gradually increases; oak declines and then rises gradually. Pine follows a smoother curve, increasing in frequency from about 6.5% at the bottom of the core to between 9 and 11% in the middle range, and then decreasing to 6% at about 20 cm. The grass profile is more jagged and follows a pattern roughly opposite to the trend in the pine profile in this same interval; more samples must be examined in order to better delineate this pattern.

(5) In the upper 20 cm. of Core #1, we observe oscillations in all the profiles. The most obvious change is in pollen concentration, which declines rapidly (due to a large increase in the sand content of the sample) and then increases again at the top.

V. INTERPRETATION

Most of the taxa whose pollen have been identified in the samples are not listed in the pollen diagram. This is because our interest in this pollen diagram is stratigraphic rather than botanical: We wished to find indicators of historical change, i.e. horizons which can be dated by association with historical events about which we have some information. Most pollen types in these cores were found in low numbers and did not follow any recognizable pattern.

One stratigraphic indicator is the frequency of chestnut pollen. Prior to the onset of chestnut blight in the 1920's, Castanea dentata was a fairly common tree in this part of the country; since that time, chestnut has virtually disappeared. Those specimens which survived were not able to reproduce sexually, and the plants which exist today never become mature trees. Thus one would expect that, in an area where chestnut was previously common, the influence of chestnut blight would show up in the pollen record as an abrupt decline in the amount of chestnut pollen.

Unfortunately, the amount of chestnut pollen found in our samples is very low, so that the difference between presence and absence may not be statistically significant. Conversely, it is not impossible that an occasional grain of chestnut pollen might turn up in sediment deposited after the appearance of chestnut blight; a definitive statement cannot be made unless a clear pattern is present.

For Core #1, one or two grains of chestnut were found in almost every sample, including the surface sample; however, the maximum number grains recorded for any sample was four. For Core #3, every sample represented on the pollen diagram contained between one and four chestnut grains, except for the two samples nearest the top. Any date based on this evidence would be subject to much suspicion; to verify the chestnut horizon in this core would require much larger pollen sums in all of the samples.

The most obvious horizon found in either of these cores is in the lower part of Core #3. This is a horizon which has analogues in many other short cores from the eastern part of the country; it represents an episode of massive forest clearing, presumably paving the way for agriculture during the period of European settlement. There is a radical shift in the oak/ragweed ratio between 80 cm. and 60 cm.; after this shift, oak never reaches its earlier high levels, nor does ragweed again approach the low frequency observed at the bottom of the core. Hickory declines from 10% to become a minor constituent in the pollen sum.

Between 70 cm. and 65 cm. the absolute pollen concentration declines rapidly and there is a peak in the SCDP profile. This can be explained as follows: If forest clearing was accompanied by an increase of erosion, the increased sedimentation rate would dilute the concentration of pollen; and the sudden influx of nutrients and organic matter from the soil into the aquatic ecosystem would result in an increase in phytoplankton productivity, which would be reflected in the SCDP peak.

The concurrent peak in the pine profile and its later decline may reflect historical patterns of land use; no explanation can be offered without careful research on the land use history of the area.

If the lower horizon represents the introduction of agriculture on a large scale, the gradual increase of oak and the decline of ragweed in the upper 30 cm. of the core may represent the return of the forest following abandonment of agriculture in this region. A rough estimate of the date of the beginning of this change would place it in the late nineteenth century, following the Civil War; once again, we require historical research to refine this estimate.

Core #3 was taken just offshore from Mason Neck, which has been a wildlife preserve for a number of years. The increased pollen concentration, the rise of pine and oak, and the decrease in ragweed in the very top of the core may be related to natural forest succession since the area became a federal preserve.

The increase of SCDP at the top of the core is probably related to an increase in the nutrient load of the river during post-World War II urban and suburban development. Whether we are seeing the direct influence of the Blue Plains sewage treatment plant or the broader result of a variety of point and non-point pollution sources is an open question at this point; examination of the other cores may shed more light on the subject.

In Core #1 we do not have a horizon indicating an episode of forest clearing. Such an episode must have occurred here; the relative levels of arboreal and herbaceous (specifically ragweed) pollen place us above the "ragweed rise". The increase of the oak/ragweed ratio above 70 cm. may in fact be correlated with the period of farm abandonment. If this is so, we are led to conclude that the sedimentation rate here is roughly twice the sedimentation rate in Core #3, unless farm abandonment occurred earlier in Alexandria than in Mason Neck.

At present, we have no explanation for the 55 cm. peak in the SCDP profile; but it is worth noting that the peak occurs concurrently with changes in the pollen profile and may somehow be connected with those changes.

The abrupt decrease in pollen concentration above 18 cm. is interpreted as a rapid increase in sedimentation rate due to postwar urban and suburban development. As this core is located just offshore from Alexandria, it is not surprising that such a change is observed here and is not observed in Core #3, where the effects of such development should be less pronounced. The rise of SCDP at the top of the core is attributable to an increase in phytoplankton productivity as a result of increased nutrient levels in the water during the same period.

The fluctuations in relative frequency of the various pollen types at the top 20 cm. of the core cannot be assigned to a specific cause at present. There may be a historical reason for these patterns; but it is possible that the extremely low concentration of pollen in some of these samples has thrown some noise into the signal.

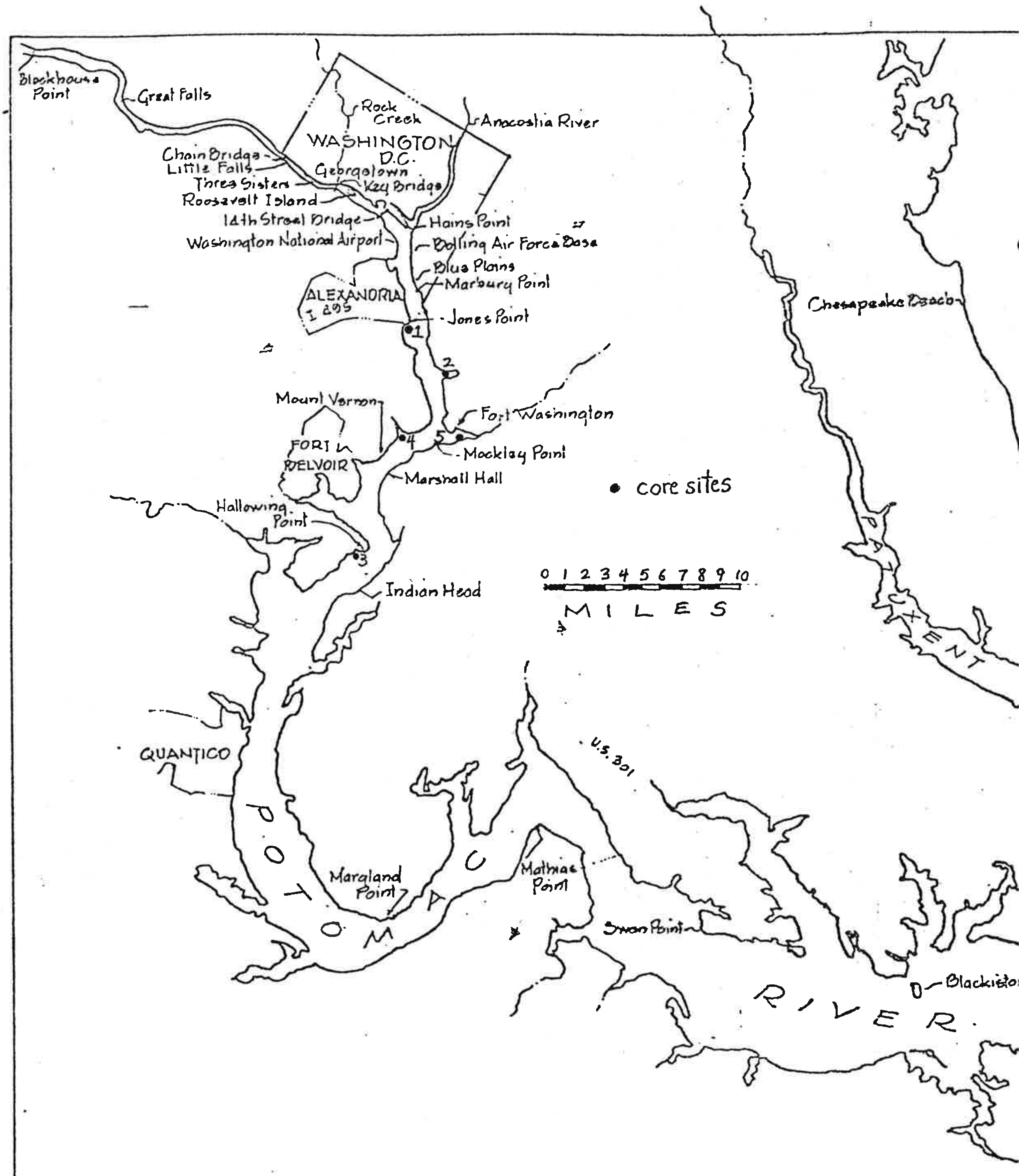
VI. SUGGESTIONS FOR FURTHER WORK

In both of the cores examined thus far, there is evidence of a stratigraphic record that can be explained by historical events; until the samples were analyzed, there was no way of knowing whether the cores would contain any useful information at all. However, the interpretation of the record will not reach an acceptable level of precision without more detailed information on the land use history of the study area. Hopefully it will be possible to date at least two levels in each core once this has been accomplished. Additional pollen samples will be analyzed in each of the cores in order to add detail to the patterns that have been observed. It should also be possible to begin work on a third core within the next two or three months, and the information obtained will be provided in a later report.

A project of this type is most successful when several independent methods are used to date horizons. The usefulness of the SCDP profile in stratigraphic studies has been documented elsewhere, and it seems to work well here in combination with the pollen record. Further work on this project would benefit from analyses of diatom stratigraphy, since diatom populations are considered to be sensitive indicators of water quality; atomic absorption analysis of trace metals would also be a useful dating method, since (for example) the first appearance of significant levels of lead in the sediment column could be correlated with the introduction of leaded gasoline onto the market.

Whether the effluent from Blue Plains has had any effect on the SCDP profiles is uncertain at this point; but the SCDP peaks which occur at the tops of both cores are not any larger than those which are found much deeper in the sediment column. As the evidence thus far is inconclusive, we would like to suggest an alternative approach: A network of surface sediment samples could be analyzed for SCDP. These samples would not be restricted to sites with an undisturbed sedimentary record, since they would be expected merely to reflect present conditions. The distribution of sampling sites could be arranged in such a way that it would be possible to detect changes in SCDP values in the vicinity of Blue Plains. It would also be possible to compare the pattern of SCDP values with the pattern of algal concentration measured in the water at times of peak productivity; this would provide a test of the reliability of the method used here. The samples could be rapidly and easily analyzed, since no pollen work would be necessary.

In conclusion, we would submit the opinion that the information retrieved thus far is indicative of the usefulness of the stratigraphic method. Careful study of bottom sediments will surely reveal much more information concerning the history and dynamics of environmental change affecting the Potomac River and the lands which drain into it.


Blockhouse Point
Great Falls
Rock Creek
WASHINGTON D.C.
Anacostia River
Chain Bridge
Little Falls
Georgetown
Three Sisters
Key Bridge
Roosevelt Island
14th Street Bridge
Hains Point
Washington National Airport
Bolling Air Force Base
Blue Plains
Marbury Point
ALEXANDRIA
I 295
Jones Point
1
2
Mount Vernon
Fort Washington
FORT BELVOIR
4
5
Mockley Point
Marshall Hall
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Hallowing Point
3
Indian Head
0 1 2 3 4 5 6 7 8 9 10
MILES
Chesapeake Beach
PATUXENT
U.S. 301
QUANTICO
POTOMAC
Maryland Point
Mathias Point
Swan Point
Blackisto
RIVER

Figure 1.

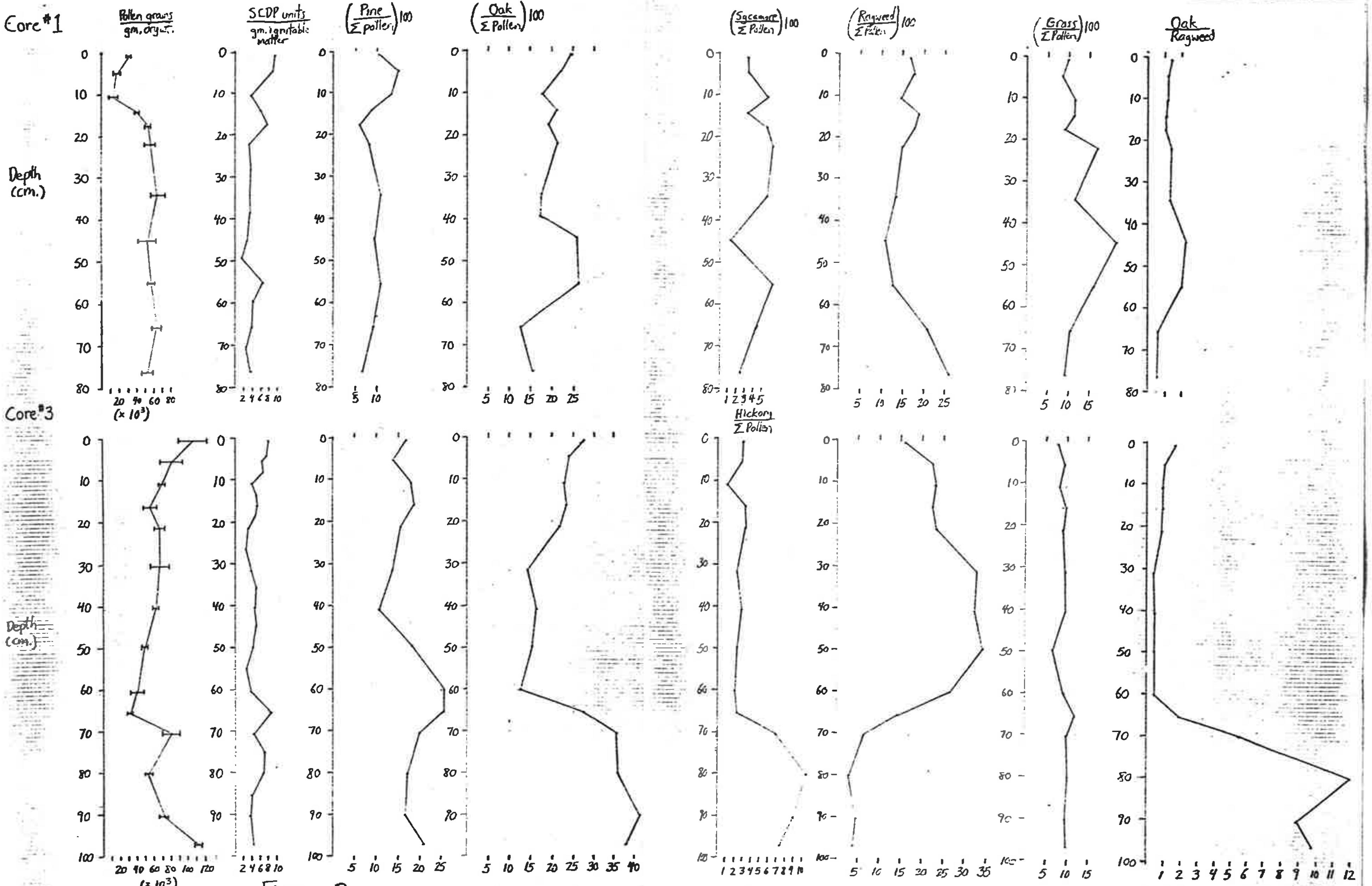
Core #1
Core #3
Depth (cm.)
Pollen grains / gm. dry wt.
(x 10³)
SCDP units / gm. ignitable matter
(Pine / Σ pollen) 100
(Oak / Σ Pollen) 100
(Sycamore / Σ Pollen) 100
Hickory / Σ Pollen
(Ragweed / Σ Pollen) 100
(Grass / Σ Pollen) 100
Oak / Ragweed
0
10
20
30
40
50
60
70
80
90
100

Figure 2.

Ecol 47. [illegible]
19[illegible]

Palynology 464

TECHNIQUE FOR PREPARATION OF LAKE SEDIMENT

1) Place sample in 15 ml. centrifuge tube [Nalgene or Teflon is nice to use as it eliminates transfer for HF (see #5)].

2) Add about 10 ml. 10% KOH, stir well, thoroughly suspending sample, and heat in boiling water bath for about 6 min. Stir during this step while in H_2O bath. Centrifuge and decant (henceforth C&D).

3) Wash twice with distilled water. C&D.

4) Add about 4 ml. of 95% ETOH to sample, stir well, and then add 6-7 ml. 10% HCl. (If sample is very calcareous, particularly marly, much frothing will take place; if so, be sure not to add too much HCl, as spillage will occur. Thoroughly suspend sample. C & D.

5) Add 8-10 ml. conc. HF (about 38-40%). Suspend sample (but do not stir with glass rod). Heat for 5 min. in boiling water bath. C & D. CAUTION. Use fume hood in this step.

6) Thoroughly suspend sample in 10 ml. of 10% HCl, heat for 5 min. in boiling water bath. C & D. prevent fluoride gels

7) Wash once with distilled water. C & D.

8) Dehydrate sample by suspending in 10 ml. glacial acetic acid. C & D. (needed to eliminate water, which is highly reactive with acetolysis mixture of next step).

9) Acetolysis: Caution, these reagents are very corrosive--use extreme care and wear safety goggles. This step must be done in fume hood. Mix 9 parts acetic anhydride to 1 part conc. H_2SO_4. This may be done by adding about 10 ml. acetic anhydride to each centrifuge tube. Stir well with spatula or glass rod, and then add 1 ml. of conc. sulfuric acid, stir, and place in boiling water bath for between 60-90 sec., but no longer (stir samples about 1-2 times while in bath). C & D. Remember, this mixture is very reactive with water, thus, pour down drain in FUME HOOD, with slow stream of running water.

10) Add about 3-4 ml. glacial acetic acid, stir, and fill tube with distilled water. C & D.

11) Wash once with distilled water. C & D.

At this point one may either mount portion of the sample in glycerin jelly, or preferably (at least to most Pleistocene workers) dehydrate sample as follows, and mount in silicone oil.

12) Wash with 95% ETOH. C & D.

Subsequent steps are described in the text of the report.