

Historical Contamination in the Southern California Bight

PART I TRACE ELEMENTS

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**Foreword
by Nathalie Valette-Silver**

Historical trends in contamination of estuarine and coastal sediments:

The composition of surface waters in rivers, lakes, and coastal areas has changed over time. In particular, changes due to the Industrial Revolution, dating from the middle of the last century, are very well known. These changes are expressed by increased levels of natural components, such as trace metals and nutrients, but also by the increase of anthropogenic compounds, such as polychlorinated biphenyls (PCBs) and pesticides.

Since the early 1960's, regulatory measures have been taken to decrease the amount of pollutants entering our waterways, but the bulk of these environmental measures were not enacted until the 1970's. Because of the scarcity of accurate data, due to the lack of sensitive techniques or of regular data collection in the past, the extent of the past pollution and the effect of the recent legislative limitations is often difficult to assess.

The analysis of sediment cores presents a way out of this dilemma. Most pollutants have an affinity for and adsorb easily onto sediments and fine particles. Therefore, by analyzing cores of undisturbed sediments it is possible to assess the historic pollution of a given system. Sediment cores reflect not only the history of pollutant concentrations but also register the changes in the ecology of a water body. For example, changes in estuarine eutrophication are reflected in the concentration of organic matter, nitrogen, and phosphorous, while lake acidification is translated into changes in diatom assemblages.

The use of cored sediments to reconstruct the chronology of coastal and estuarine contamination is not, however, devoid of problems and caution must be exercised. Sediment mixing by physical or biological processes can obscure the results obtained by such studies, and sophisticated methods must be used in these cases to tease out the desired information.

The NS&T Core Project

Between 1989 and 1996, the National Status and Trends Program sponsored research that gathered information on long term trends in contamination of US coastal and estuarine sediments. In this project, ten areas have been targeted. They include:

- 1) On the East coast:
 - Hudson/ Raritan estuary
 - Long Island Sound marshes
 - Chesapeake Bay
 - Savannah Estuary
- 2) On the Gulf coast:
 - Tampa Bay
 - Mississippi River Delta
 - Galveston Bay
- 3) On the West coast:
 - Southern California Bight
 - San Francisco Bay
 - Puget Sound

Presently, all the studies are completed and reports are, or will soon be, directly available from the cooperators. One of the most important results of the NS&T studies and of other similar studies reported in the literature, is the observed decline in recent years of many organic and inorganic contaminants in the sediments. It is very encouraging to know that mitigating measures taken in the 1970's have been effective. This has shed a hopeful light on the potential success of future efforts to curb even more coastal and estuarine pollution.

In an effort to widely disseminate the results of these studies, the NS&T Program, in collaboration with the authors, is publishing some of the reports as NOAA Technical Memoranda. This study covering the Southern California Bight is the fifth one to be published in this series. In this case, the published Technical Memorandum includes two reports produced by two different groups of researchers. The first part is dedicated to metal contaminants and the second part to organic compounds.

**Part I: Historical Contamination of the
Southern California Bight - Metals**

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Executive Summary

We report here downcore distribution of 16 elements measured by ICP-MS and by neutron activation analysis in 8 cores collected in the Southern California Bight. All cores were dated by ^{210}Pb (via ^{210}Po) to construct the chronology of the sediment layers. Based on the ^{210}Pb chronology, the lengths of these cores represent from 150 to 230 years of deposition, period covering the entire history of pollution from human activities in the Southern California Bight.

The profiles obtained for eight elements (Cr, Cu, Zn, Ag, Cd, Sn, Hg and Pb) are generally characterized by increasing anthropogenic inputs around the turn of the century resulting in a subsurface maxima around 1970. The near-surface decreases reflect recent improvements in waste water treatment and more stringent regulatory controls on industrial waste disposal. For Ba the results indicate that excess Ba was contributed by off-shore dumping rather than sewage discharge.

The distribution of the other elements (Al, Si, Mn, Fe, Ni, As, and Se) is different from the previous group. Al and Si distributions reflect the mineral composition and grain size of the sediments. Fe and As profiles show diagenetic signals that are especially strong in deep-basin cores. Finally, Mn, Ni, and Se do not show any systematic pattern.



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Introduction

The three largest municipal outfalls (JWPCP, Hyperion and CSDOC) in the Southern California Bight discharge treated sewage effluents into the shelves bordering the Santa Monica and San Pedro Basins, off the metropolitan Los Angeles/ Orange County area (Fig. 1). Since 1971, the Southern California Coastal Water Research Project (SCCWRP) has conducted systematic analysis of effluent flow and concentrations of trace contaminants. Mass emissions estimated from the monitoring data indicate that these three outfalls account for more than 90% of most heavy metals discharged from all 16 marine outfalls along the coastline of the Southern California Bight in the past two decades. Numerous studies have shown that metal deposited in the coastal sediments in the past several decades contained a significant anthropogenic component, often far exceeding their natural baseline levels. The impact of sewage-derived material on the coastal environment is an issue of considerable public concern and scientific interest.

Chow et al. (1973) studied historical deposition records of Pb in cores collected in 1971 from the deep Santa Monica and San Pedro Basins, which showed an increase from a baseline level established prior to the early 1900s to maximum concentrations at the top of the core. In 1971, the flux of anthropogenic Pb was 3-6 times higher than the flux of natural Pb. Based on isotopic data it was concluded that anthropogenic Pb was derived from the combustion of leaded gasoline. Using the same sediment cores, Bruland et al. (1974) obtained profiles for Cr, Cd, Zn, Cu, Ag, V, and Mo which also showed the same general anthropogenic signal. Later, Ng and Paterson (1978) studied Pb and Ba in cores collected in the same area and were able to show that Pb concentrations began to decrease after a peak in 1970. This is in agreement with the history of gasoline consumption and the phasing out of leaded gasoline since 1971. These authors were also able to estimate the contribution of sewage output (ranging from 2/3 to 3/4) to the total anthropogenic Pb.

During the DOE sponsored CaBS (California Basin Study) Program, a series of sediment cores collected from 1985 to 1990 were studied, not only to update the history of metal pollution, but also to determine budgets and pathways of sewage metals in the Santa Monica and San Pedro Basins (Finney and Huh, 1989 a, b; Huh et al., 1990). Metals investigated in the CaBS study included Cr, Zn, Pb, Sb, Ba, and Cu.

The work reported here is part of a concerted effort with Indira Venkatessan, who is studying the chronology of organic compounds contamination in the same cores. Compiled in this report are data on sediment chronology and distribution (spatial and temporal) of the NS&T suite of metals in seven sediment cores collected during 1990-1991. This work was supported by a grant from the NOAA National Status and Trend Program. We thank Dick Kovar, Chi Meredith and Andy Ungerer for laboratory assistance, and Nathalie Valette-Silver for her comments throughout the course of this project.

Sample collection and preparation

Sediment cores used in this project are listed in Table 1 and their locations are shown in Figure 1. Cores CaBS XI-1 and XI-4 were collected onboard R/V New Horizon in January 1990 from the 11th cruise of the CaBS program; they were not studied previously and ideally suited for the purpose of the NS&T Project. Cores NOAA-I through VI were

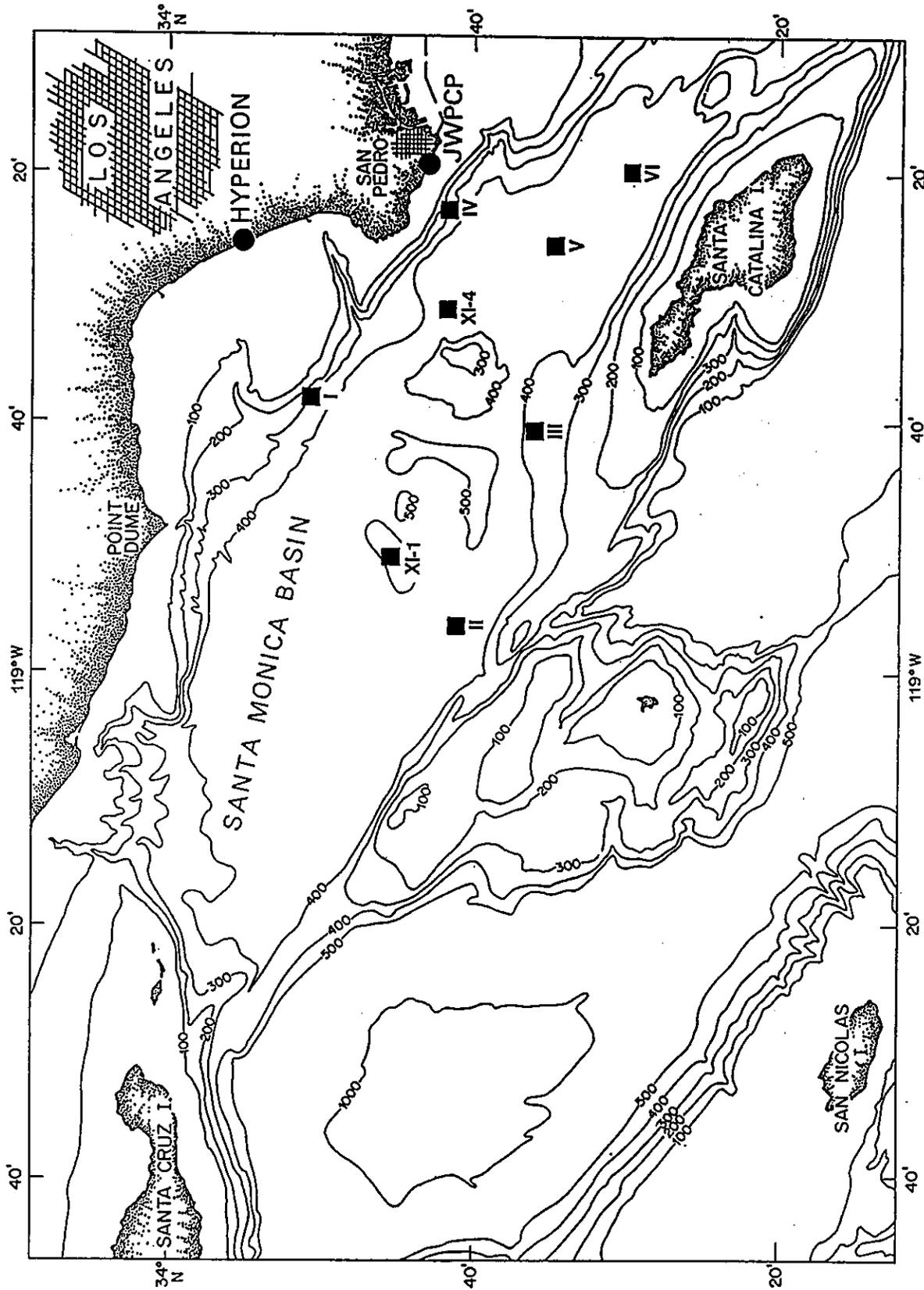


Figure 1. Map showing the bathymetry of the Santa Monica-San Pedro Basin. Solid squares indicate locations of box cores used in this study. Also shown are the two largest municipal sewage outfalls (JWPCP and Hyperion) in the Southern California Bight.

collected in September 1991 onboard R/V *Sea Watch*; the cruise was organized by Dr. Indira Venkatesan of UCLA, under the support of and specifically for the NOAA NS&T Program.

These cores were collected using a Soutar box corer capable of sampling sediments with minimum disturbance, as evidenced by downcore distributions of short-lived radionuclides (e.g. ^{234}Th and ^{228}Th) and Pu, an anthropogenic transient tracer (Huh *et al.*, 1987; Wong *et al.*, 1992). The coring sites were located with two applications in mind: (1) to update the latest history of pollution resulting from human activities, as mandated by the NS&T Program, and (2) to enhance spatial coverage and fill existing data gaps. This can be seen in Figure 2 which shows the locations of new cores used in this study in relation to all previous cores collected/studied during the CaBS Program from 1985 to 1990. CaBS XI-1 and NOAA-I, II and VI were collected near previous key CaBS sites (to serve the first purpose), while CaBS XI-4, NOAA-III, IV and V were from areas not occupied previously (to serve the second purpose).

The CaBS cores were sectioned onboard immediately upon collection. The subsamples were kept frozen until further processing and analysis in the lab. The NOAA cores were frozen on board and sectioned after the cruise in Dr. Venkatesan's lab at UCLA. The subsamples were weighed before and after drying at $\sim 55^\circ\text{C}$. From the weight loss sediment dry weight on salt-free basis were calculated using the equation:

$$\text{Salt-free dry weight} = \text{bulk dry weight} \times \frac{1 - \frac{1000}{1000 - S} \times \frac{W_{\text{H}_2\text{O}}}{100}}{1 - \frac{W_{\text{H}_2\text{O}}}{100}}$$

Where $W_{\text{H}_2\text{O}}$ (in %) is weight content of water and S (in ‰) is salinity of interstitial water (taken to be that of bottom water). All measurements (^{210}Pb and metals) reported below are based on salt-free basis.

^{210}Pb analysis

All cores were dated by ^{210}Pb (via ^{210}Po) to construct the chronology of the sediment layers, as described in our previous work (Huh *et al.*, 1987; 1990; 1992). The results are summarized in Tables 2-9 (one table for each core). Below each table is a figure showing the concentration of excess ^{210}Pb as a function of cumulative mass (on salt-free basis) and the sedimentation rate (S) resulting from least-square fitting. The cumulative mass (g/cm^2) is integrated sediment dry weight down core, calculated by:

$$\text{Cumulative mass} = \sum Z_i \rho_i \left(1 - \frac{1000}{1000 - S} \times \frac{W_{\text{H}_2\text{O}}}{100} \right)$$

Where Z_i is the thickness (in cm) of the i th sampling layer and ρ_i (g/cm^3) is wet density of

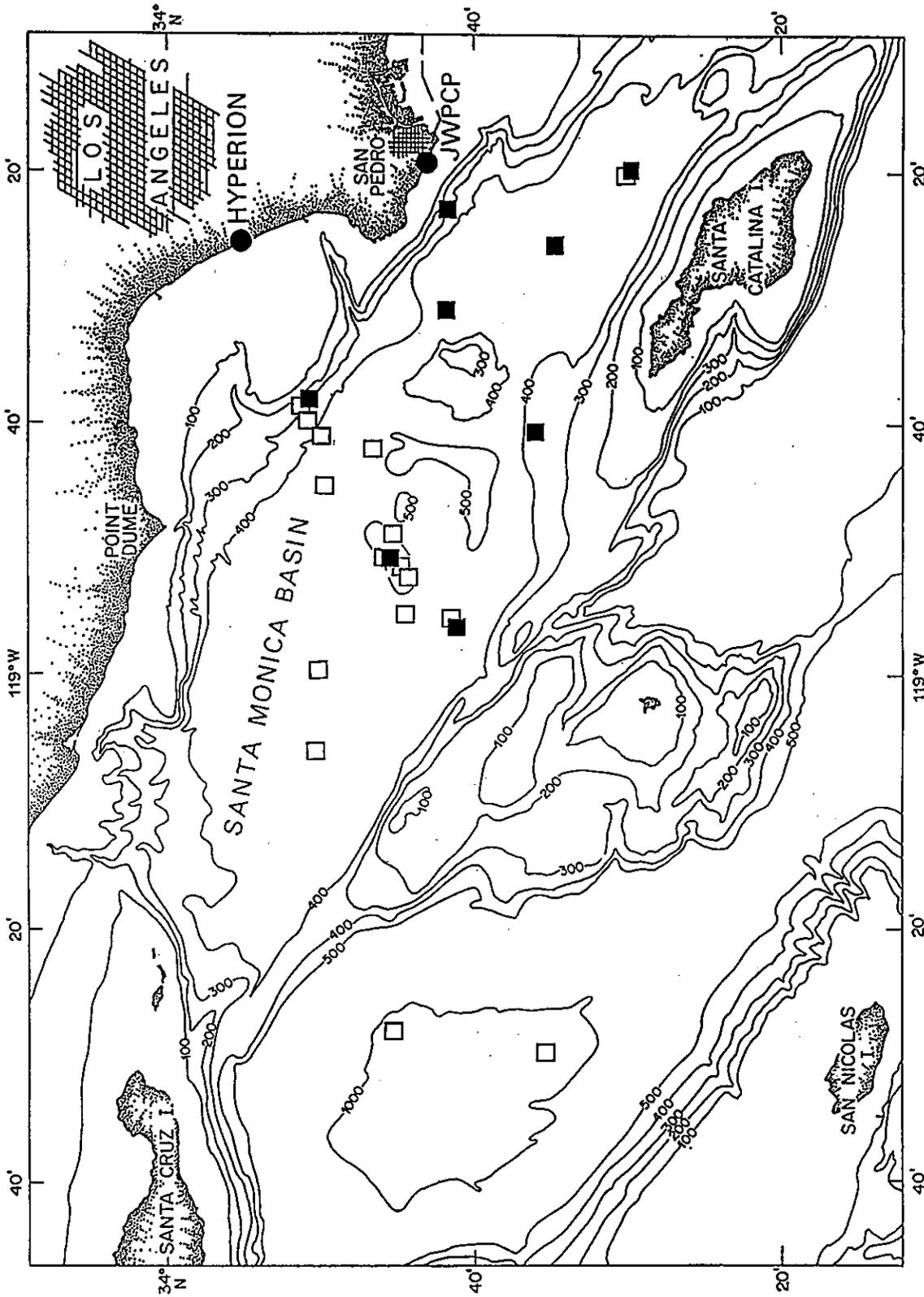


Figure 2. Locations of cores used in this study (solid squares) and of previous cores studied under the CaBS Program (empty squares).

that same layer.

From the indicated sedimentation rate, time of deposition for each sampling layer is calculated by:

$$\text{Time of deposition} = \text{time of sample collection} - \frac{\text{cumulative mass}}{S}$$

The effect of sediment mixing, indicated by a less steep ^{210}Pb gradient in the top ~5 cm, is obvious in cores underlying oxic bottom waters at water depths <800 m. In such case, with the exception of NOAA-IV, time of deposition is calculated using sedimentation rate derived from below the surface mixed layer. Because of the very fast sedimentation rate due in large part to large flux of sewage particles near the JWPCP outfall, the distribution of ^{210}Pb in sediment core NOAA-IV primarily reflects radioactive decay; the effect of mixing is considered to be relatively unimportant in modifying downcore distribution of ^{210}Pb (and trace metals).

Based on the ^{210}Pb chronology the lengths of these cores represent 150-230 years' deposition, which should cover the entire history of pollution from human activities in the Southern California Bight.

Metal analysis

1. Sample preparation

For metal analysis approximately 0.1 g of dried sample was weighed into a 125 ml LDPE acid-washed bottle to which 1 ml of DDW had been added. Then 8 ml of 1:1 concentrated HF/HNO₃ (GFS double distilled) was added and the bottle was squeezed to expel about 1/3 of the air to allow for expansion in oven. The bottle was capped, shaken, and placed in a 70°C oven. After digesting overnight, the bottle was removed from the oven and cooled for 15 minutes. Then 50 ml of 4% (w/v in DDW) H₃BO₃ (GFS 99.999%) was added and the bottle was squeezed again, capped, shaken, and returned to the oven. After 2 hours, the bottle was removed and cooled for 15 minutes. Finally 41 ml of DDW was added to bring the total volume to 100 ml. The sample was then ready for ICP-MS and AAS.

Samples for ICP-MS and AAS (both flame and graphite-furnace) were diluted as required with standards and blank matrix prepared simultaneously. As, Se, Sn and Sb were measured by ICP-MS. Al, Si, Mn, Fe and Ba were measured by flame AAS for which 1000 ppm CsCl was added to control ionization. Other metals (Cr, Ni, Cu, Zn, Ag, Cd, and Pb) were measured by GF AAS.

2. Quality assurance and control

As required by the NS&T Program, we participated in the QA/QC exercise by analyzing two calibration standards, "Fish Q" and "Sediment R", provided by NRC. Due to instrumentation problems with ICP-MS as of the data submission deadline, we were able to report data for only 10 elements which were measured by AAS. Comparison between data of ours and other participating laboratories' indicated that the overall quality of our data was very good indeed. Although we have no experience in analyzing biological samples, our overall results for Fish Q were nevertheless better than two-thirds of other labs'. The results for sediment R have direct bearing on our NS&T project and are what we are most concerned about. The quality of our Sediment R data (see Table 10) was among the top 20%. In terms of precision (based on measurements made on five replicates prepared in a batch), our results are by far the best. As regards accuracy, the mean concentrations we reported are well within the range of NRC accepted values, with the exception of Ni. Our mean Ni value is ~40% higher than the NRC accepted mean value. However, this has no adverse impact to our work as Ni is not a "pollutant" metal in the Southern California Bight (see later).

As originally proposed, we initially measured all elements required for the NS&T Program by ICP-MS, but the overall results were disappointing. Because of that we resorted to AAS to obtain data for the 10 elements mentioned above. Our AAS is not equipped to measure As, Se, Sn and Sb, however. Therefore, for now, we will report the ICP-MS data for these four elements, although their analytical errors ($\pm 1\sigma$) are much greater - generally in the range 20-30% based on triplicate runs.

3. Distribution/inventories of anthropogenic metals in sediments: implication on the input history, sources, and pathways of pollutants

We report here downcore distribution of 16 elements in 8 cores. The results are summarized in Tables 11-18. Concentrations of eight elements (Cr, Cu, Zn, Ag, Cd, Sn, Ba and Pb) which clearly show anthropogenic inputs are plotted *versus* time of deposition (A.D.). To gain a spatial perspective of the distribution of these metals, the plots are inseted in the map, as presented in Figures 3-10. Also indicated on Figs. 3-10 (and summarized in Table 19) are inventories of the excess, anthropogenic component of metals (X_{ex}) in each individual core, which were calculated by integrating the metal profiles down core using the equation:

$$\int X_{ex} = \sum \left[\left(\frac{X}{Al} \right)_i - \left(\frac{X}{Al} \right)_{bkgd} \right] \times Al_i$$

Where $(X/Al)_i$ is the metal-to-Al concentration ratio in the *i*th sampling layer, and $(X/Al)_{bkgd}$ is the same ratio in uncontaminated sediments, determined from sediments deposited prior to 1900.

These profiles are generally characterized by subsurface maxima around 1970. Increases

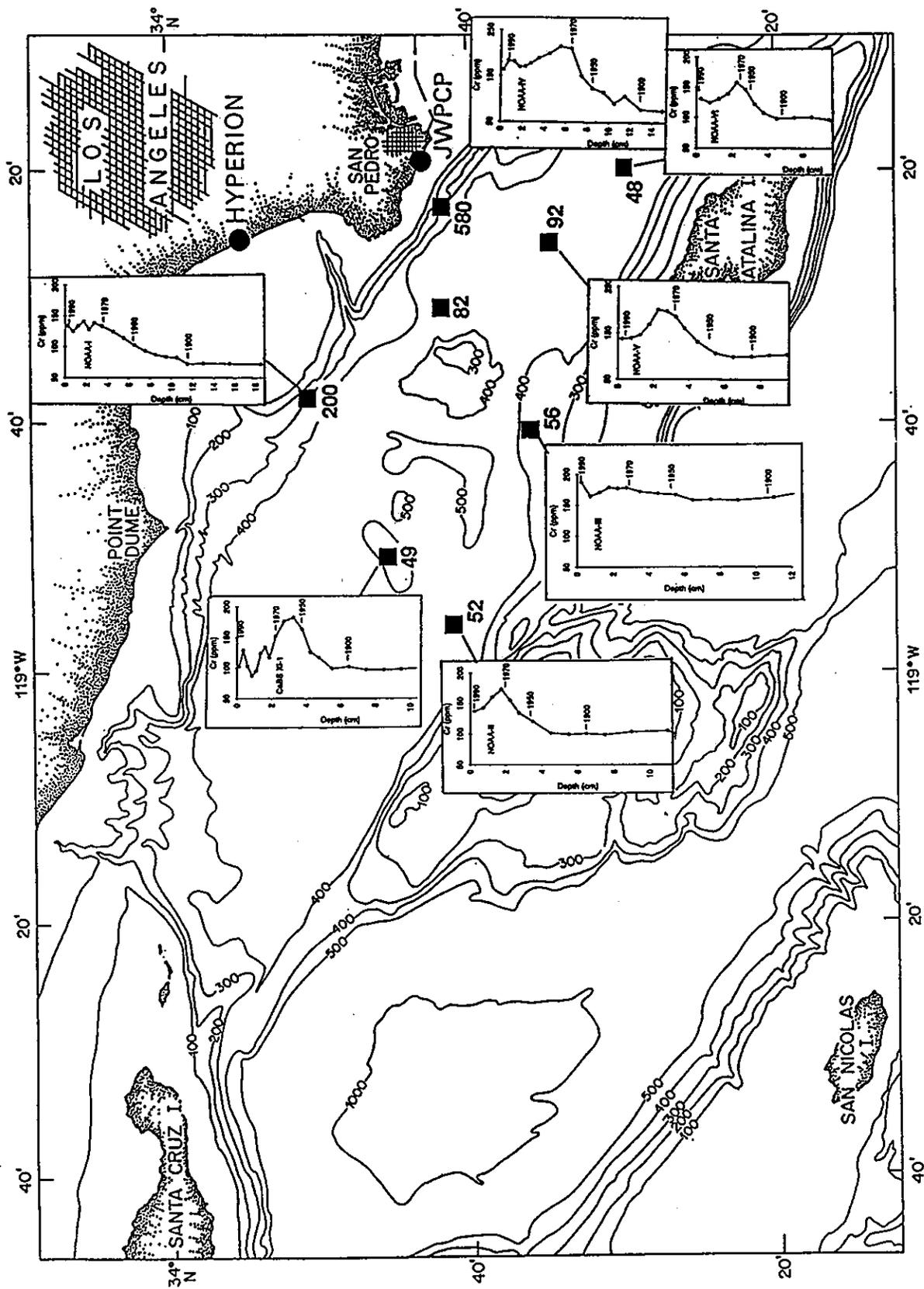


Figure 3. Concentration of Cr as a function of time of deposition at the coring sites. Numbers next to solid squares are downcore inventories of excess Cr (in $\mu\text{g}/\text{cm}^2$).

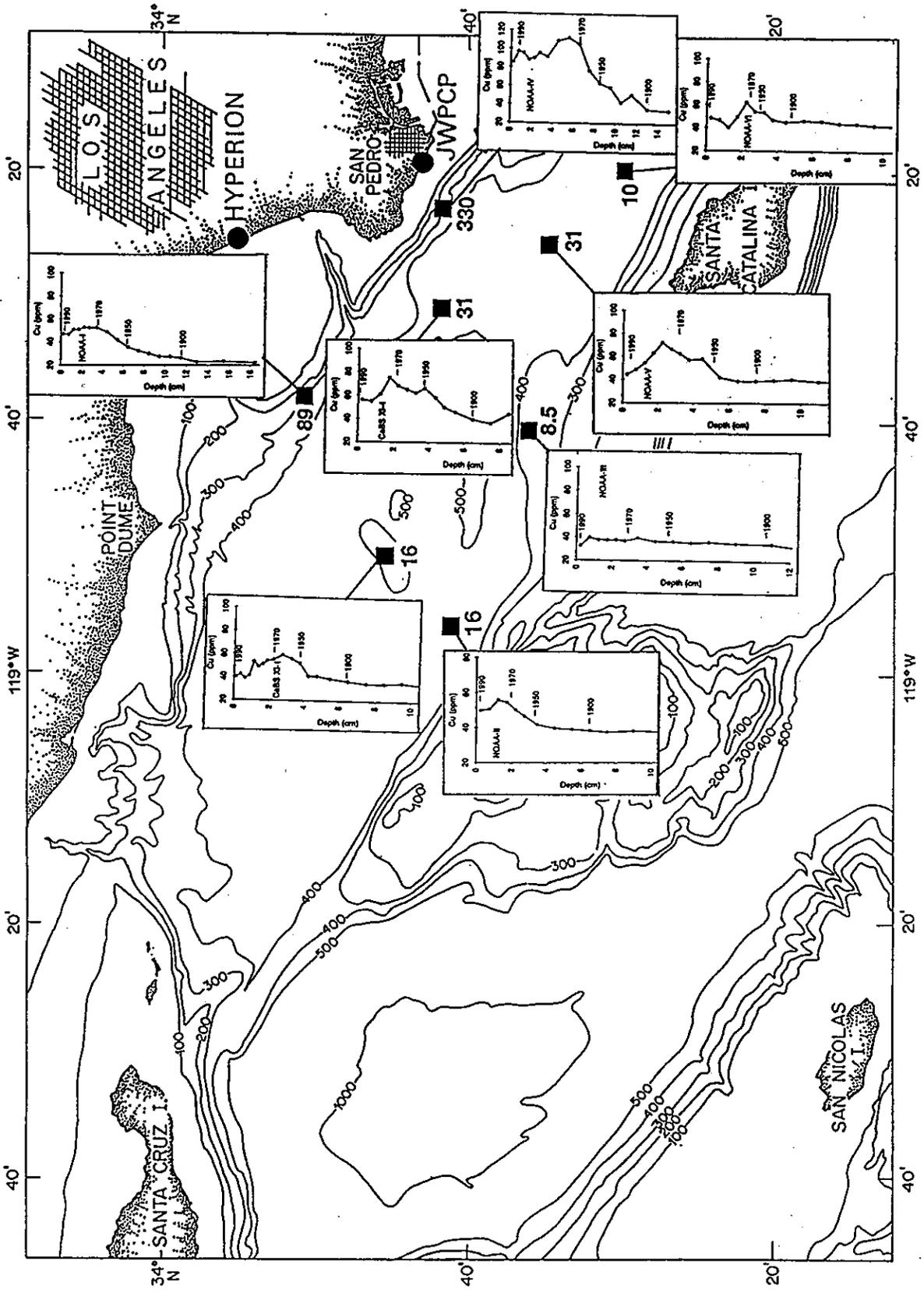


Figure 4. Concentration of Cu as a function of time of deposition at the coring sites. Numbers next to solid squares are downcore inventories of excess Cu (in $\mu\text{g}/\text{cm}^2$).

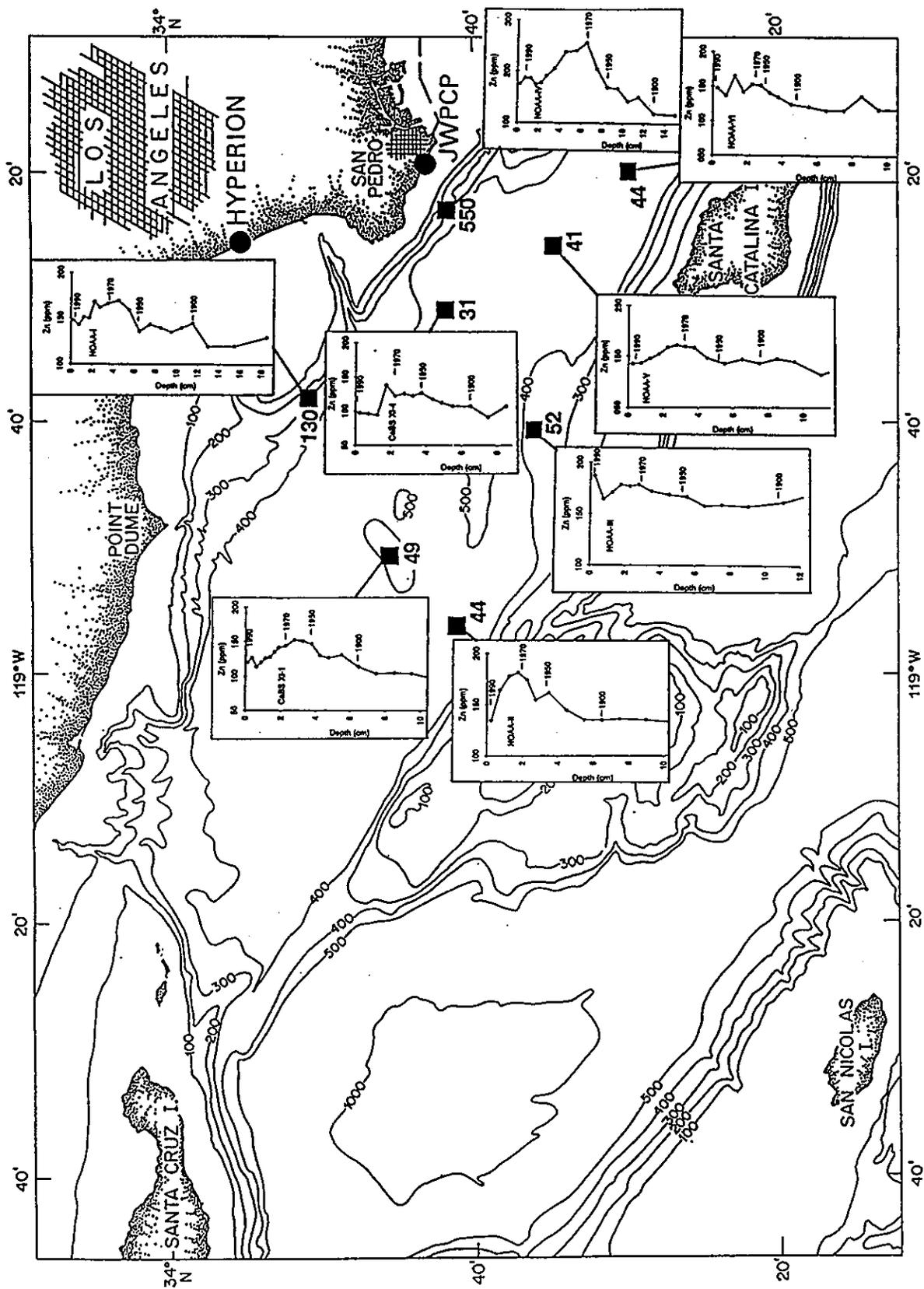


Figure 5. Concentration of Zn as a function of time of deposition at the coring sites. Numbers next to solid squares are downcore inventories of excess Zn (in $\mu\text{g}/\text{cm}^2$).

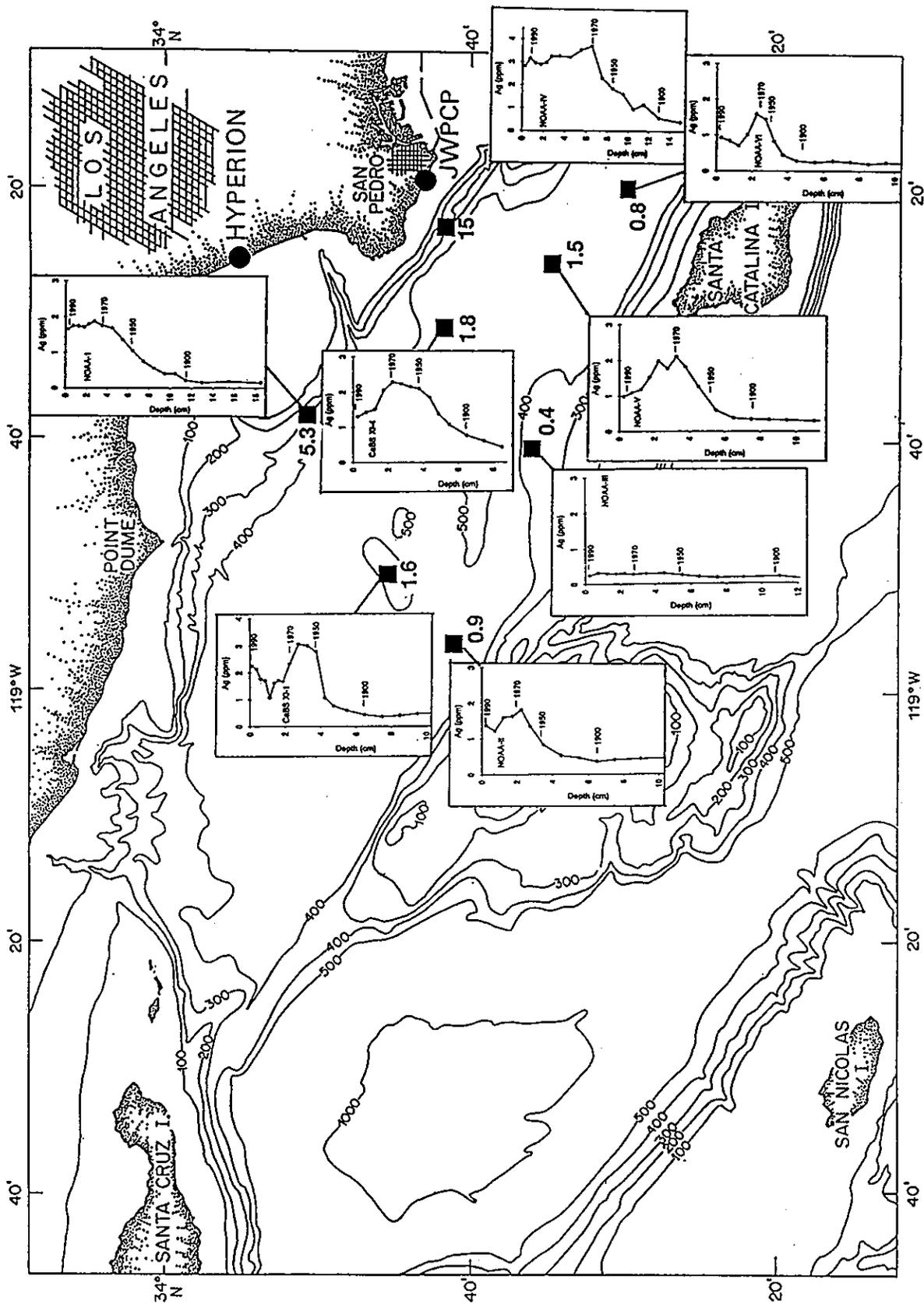


Figure 6. Concentration of Ag as a function of time of deposition at the coring sites. Numbers next to solid squares are downcore inventories of excess Ag (in $\mu\text{g}/\text{cm}^2$).

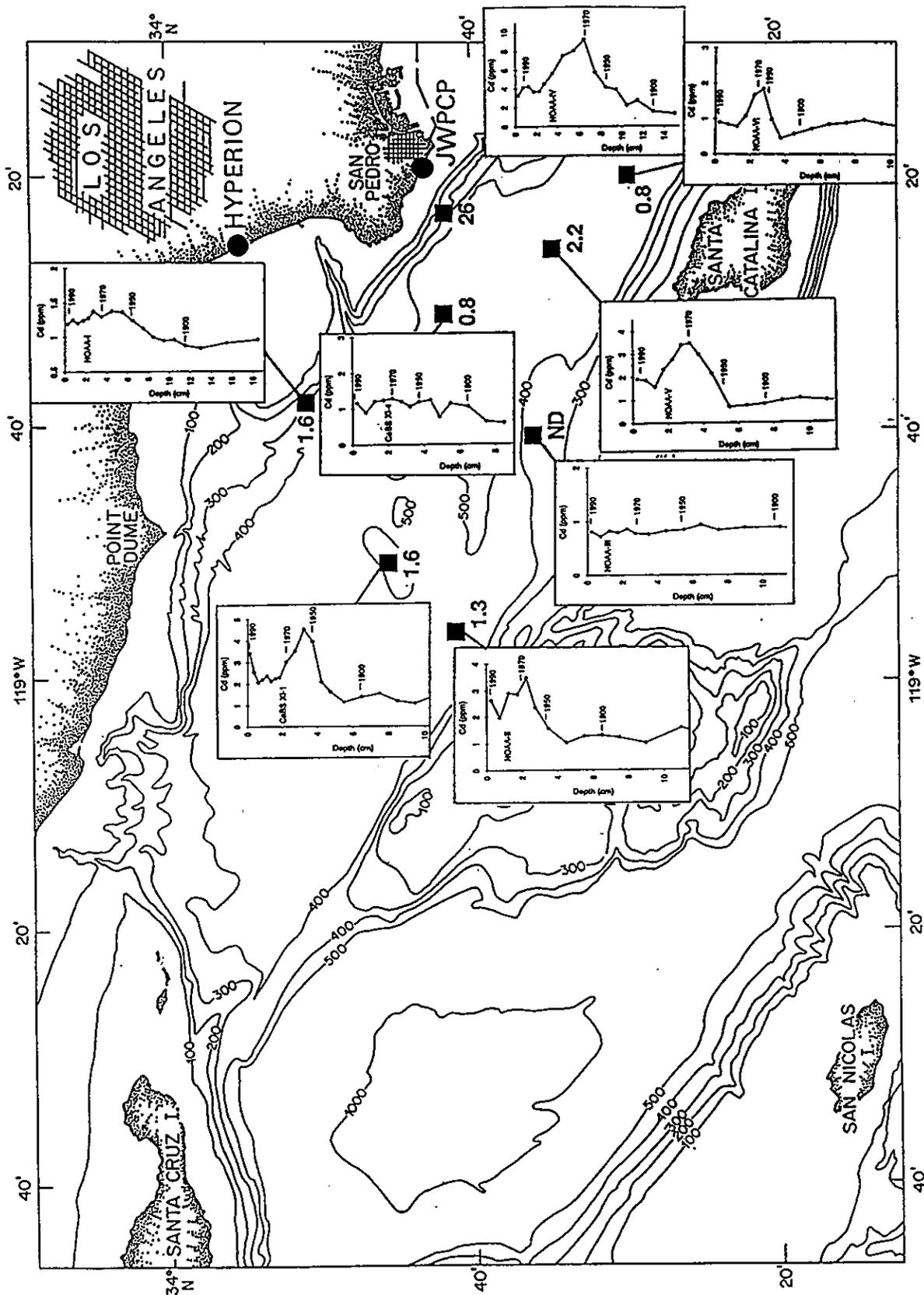


Figure 7. Concentration of Cd as a function of time of deposition at the coring sites. Numbers next to solid squares are downcore inventories of excess Cd (in $\mu\text{g}/\text{cm}^2$).

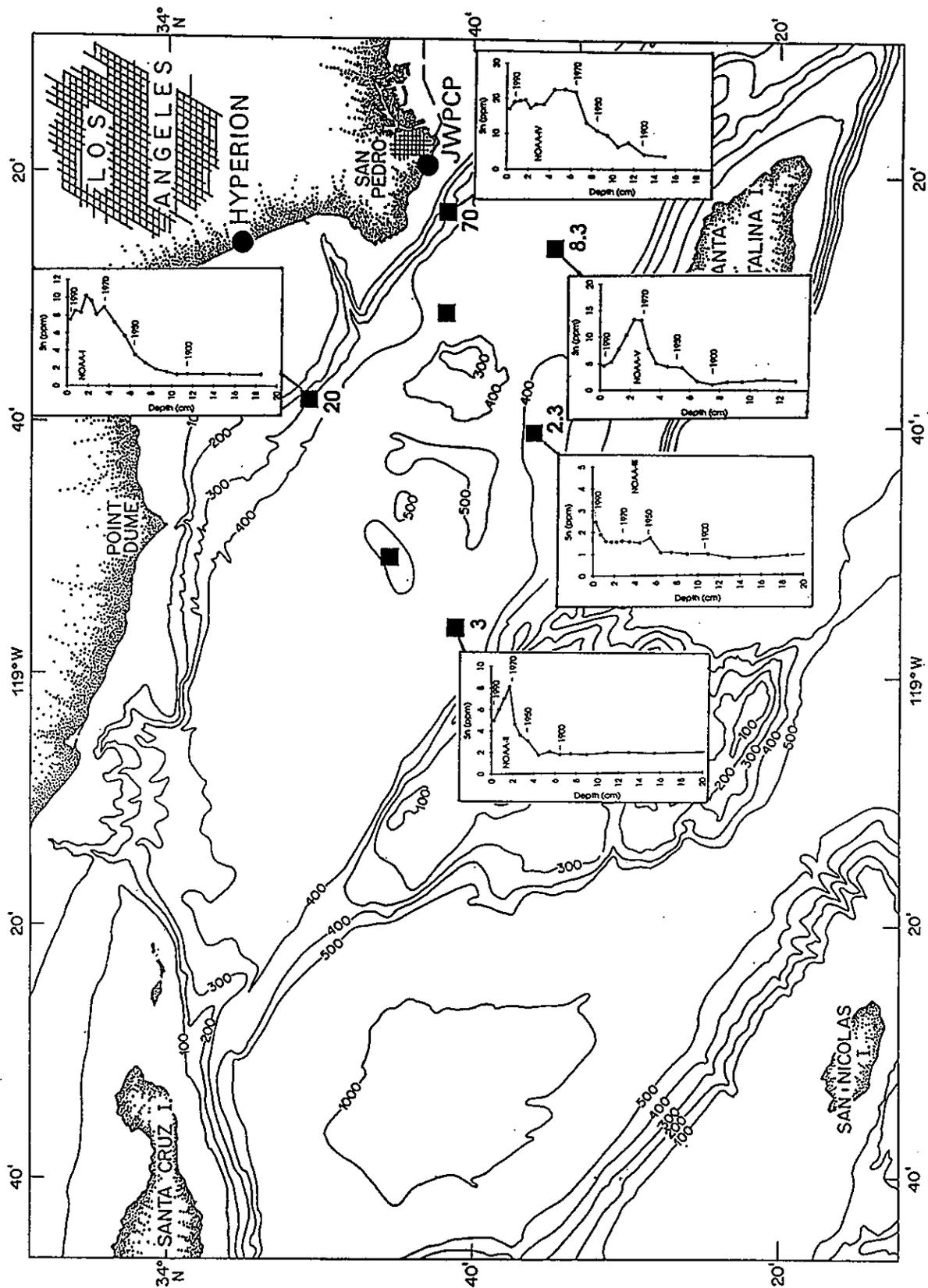


Figure 8. Concentration of Sn as a function of time of deposition at the coring sites. Numbers next to solid squares are downcore inventories of excess Sn (in $\mu\text{g}/\text{cm}^2$).

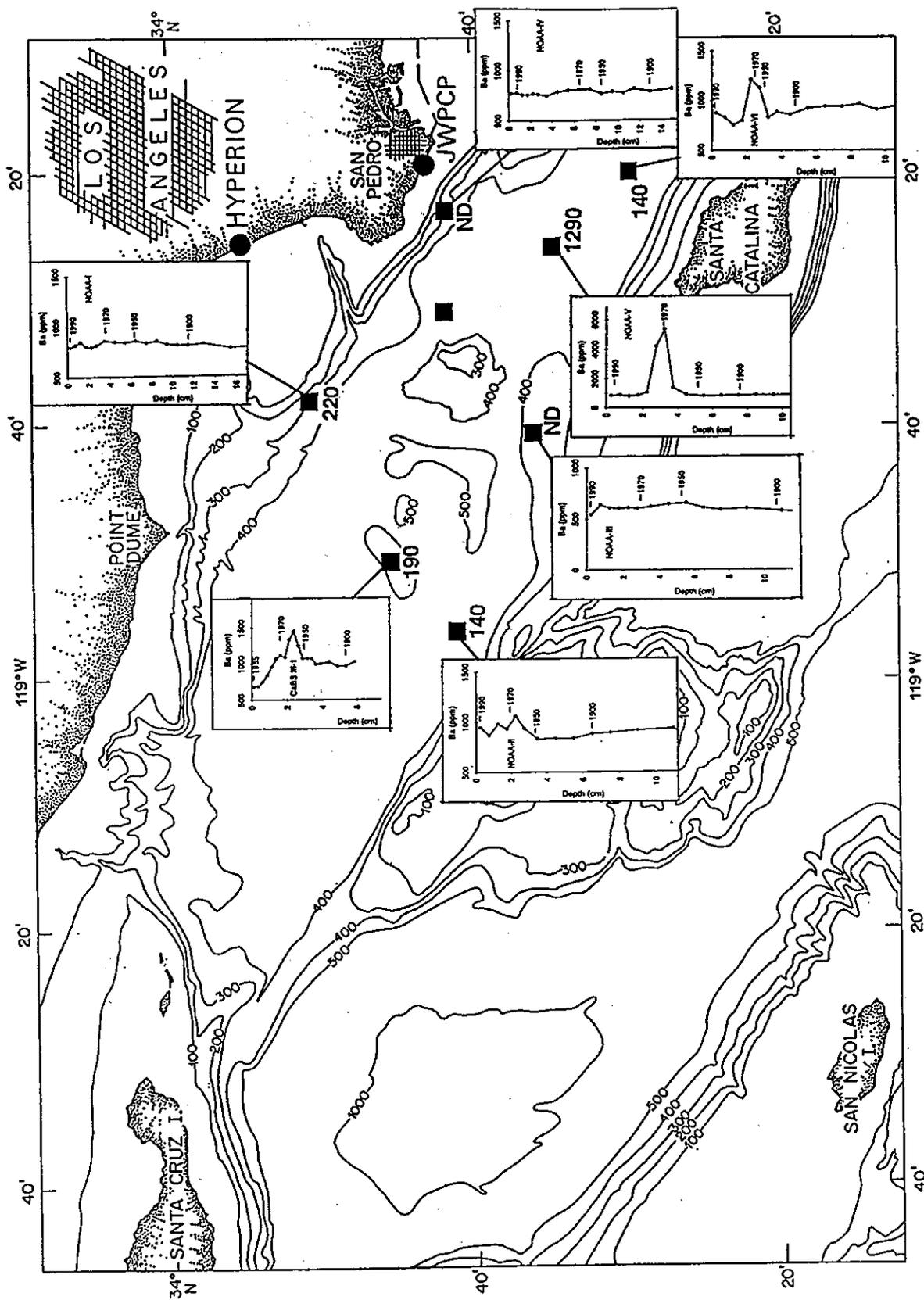


Figure 9. Concentration of Ba as a function of time of deposition at the coring sites. Numbers next to solid squares are downcore inventories of excess Ba (in $\mu\text{g}/\text{cm}^2$).

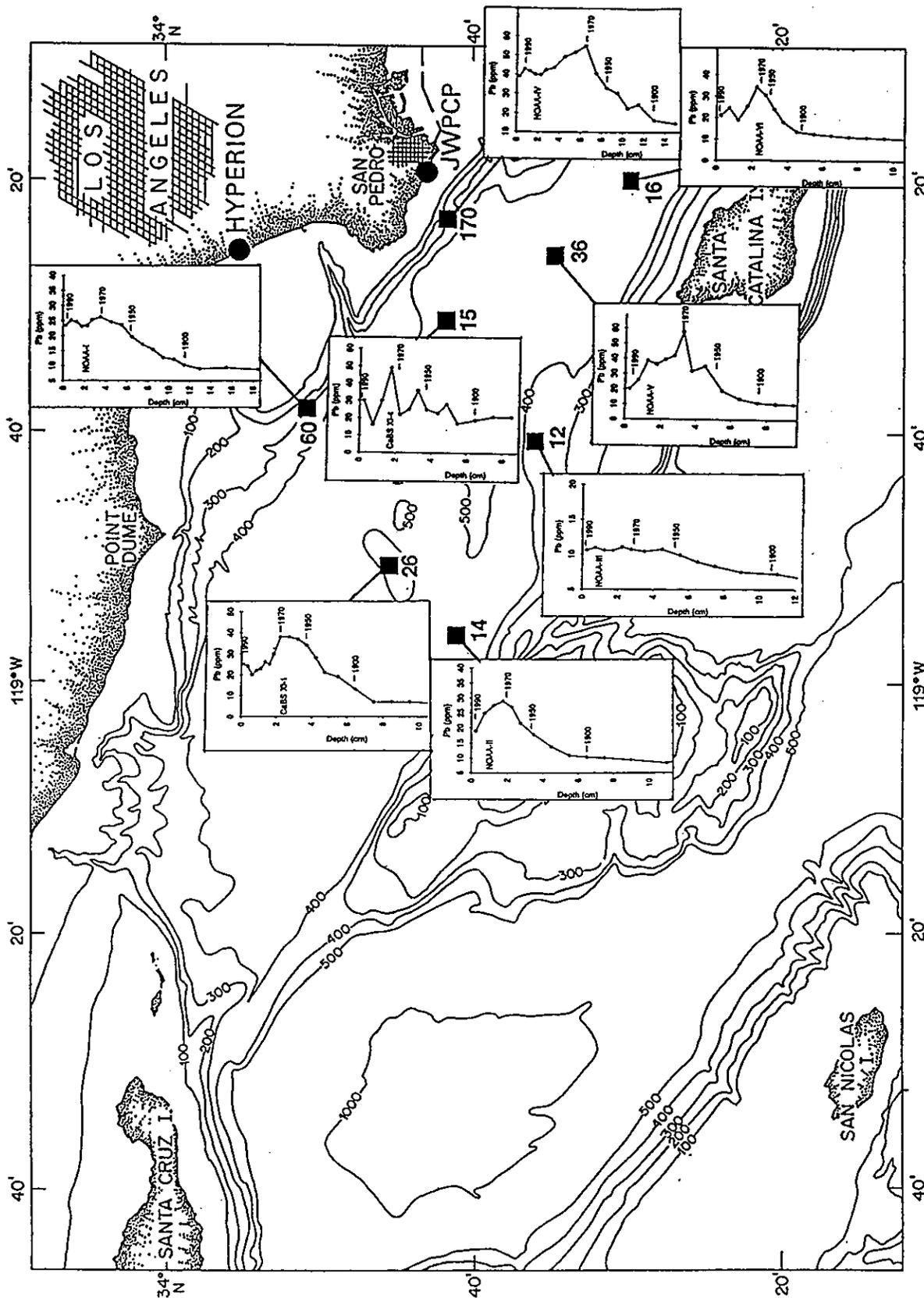


Figure 10. Concentration of Pb as a function of time of deposition at the coring sites. Numbers next to solid squares are downcore inventories of excess Pb (in $\mu\text{g}/\text{cm}^2$).

from the bases of these cores are consistent with increasing anthropogenic inputs around the turn of the century. The near-surface decreases reflect recent improvements in waste water treatment and more stringent regulatory controls on industrial waste disposal (Fig. 11), as we have observed in cores collected during 1985-88 (Finney and Huh, 1989a, b; Huh *et al.*, 1992). The improvements have been maintained since then, as testified by the low surface concentrations which are close to baseline levels. Among the eight elements illustrated here, Cr, Cu, Zn, Ag, Cd, Sn, and Pb exhibit similar downcore and spatial distribution patterns. Inventories of this group of metals decrease sharply away from the sewage outfalls in the shelf/slope region and are somewhat homogeneous in the vast, deep Santa Monica/San Pedro Basin (>900 m).

The distribution pattern of Ba is distinctly different, as shown in Fig. 12. Unlike the other seven metals for which the highest concentration/inventories are found in NOAA-IV, indicating sewage outfalls as their primary source, excess Ba is not detectable in NOAA-IV. Instead, the highest excess Ba inventory was found at station NOAA-V (Fig. 9) in the deep San Pedro Basin. Compared with sewage-derived metals, the Ba peaks are sharper and located deeper in the cores. All these clearly indicate that excess Ba was contributed by offshore dumping rather than sewage discharge. As mentioned in our proposal, in the mid-1980s Allan Chartrand of the Regional Water Quality Control Board in Los Angeles compiled and reviewed all available records of ocean dumping in the Southern California Bight (Chartrand *et al.*, 1985). The review indeed revealed records of dumping in offshore waters over the period 1947-61, principally in the San Pedro Basin. These included the acid and caustic wastes of a petroleum refinery, which is probably most responsible for the high Ba content in core NOAA-V, and the acid sludge wastes of the Montrose Chemical Company, the world's largest manufacturer of DDT. We predict that NOAA-V will have the highest DDT content among these cores, which will be borne out from Dr. Venkatesan's results.

Inventories calculated here for cores NOAA-I, NOAA-VI and CaBS XI-1 compare fairly favorably with those reported previously at nearby sites CaBS I-40, CaBS V-9 and CaBS III-1, respectively, as shown in Table 20. This reflects the general accuracy/consistency of our metal analysis over the years. Therefore, the new data can be integrated with old data to update the history of metal pollution and re-calculate the basin-wide budgets of anthropogenic metals, which will be the main thrust of a paper we plan to write.

During the CaBS program, we have obtained most complete data for Cr, Zn and Pb and thus calculated basin-wide budgets of these three elements (Huh *et al.*, 1990). Figure 13 shows that the spatial distribution patterns of Cu, Cd, Ag and Sn are very similar to that of Cr, indicating their common source, similar geochemical behavior and transport pathways. So, budgets of these four elements in the Southern California Bight can be reasonably estimated by comparing their downcore inventories with that of Cr. The Ag/Cr, Cd/Cr, Sn/Cr and Cu/Cr inventory ratios at NOAA-IV are 0.026, 0.045, 0.13 and 0.57 respectively. If these ratios are representative of those in Palos Verdes Shelf sediments, as we believe they are (due to proximity), then budgets of anthropogenic Ag, Cd, Sn and Cu in the Palos Verdes Shelf region would be ~60, ~100, ~300 and ~1300 metric tons, respectively (calculated by

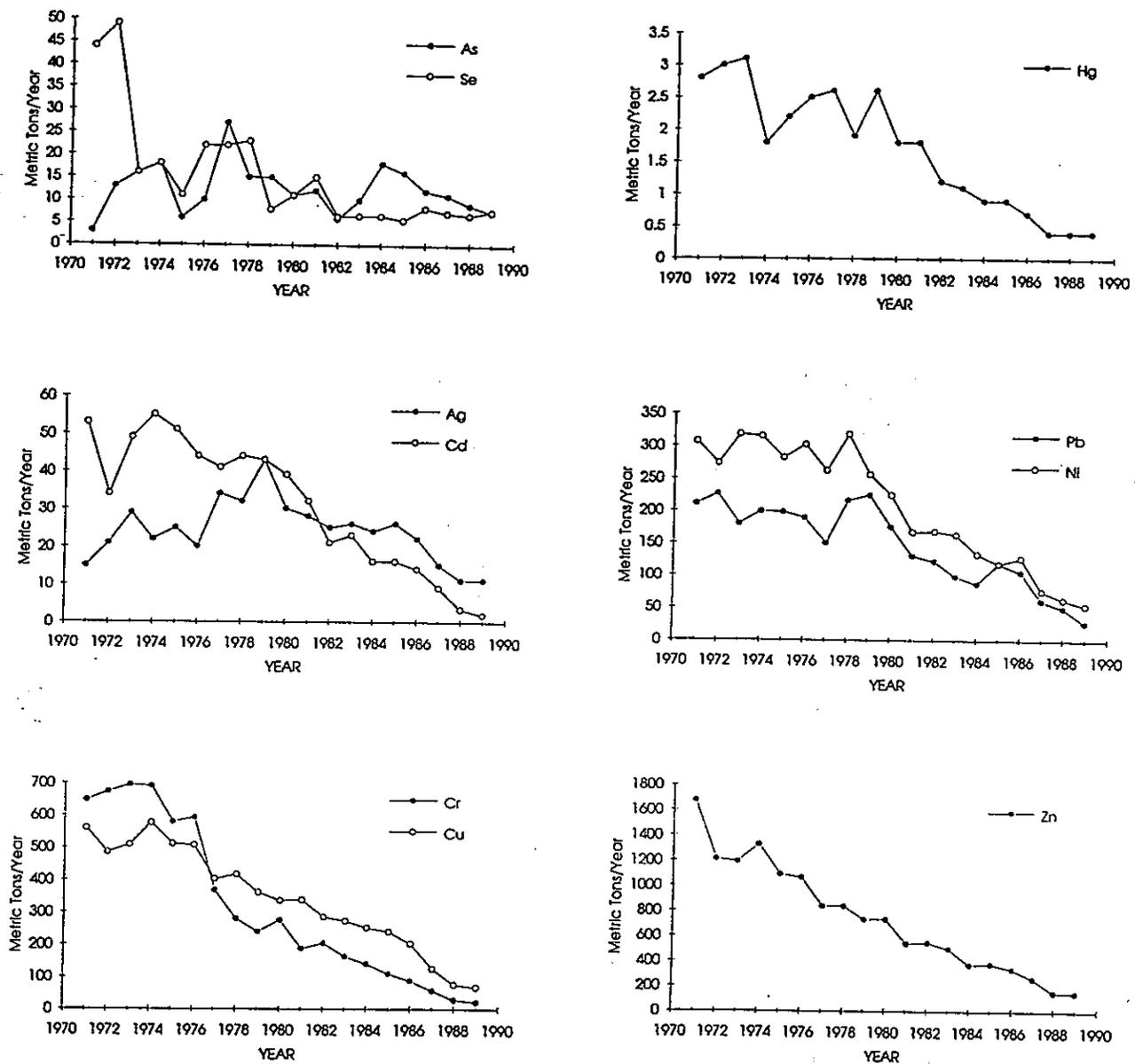


Figure 11. Combined mass emissions of heavy metals from the four largest municipal wastewater treatment facilities.

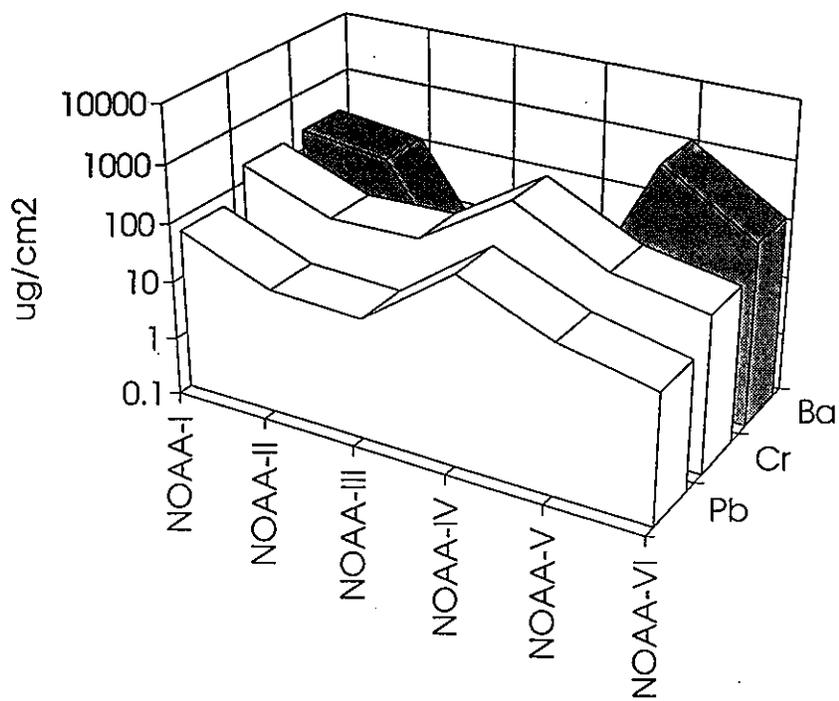


Figure 12. Variation of Cr, Pb and Ba inventories between NOAA NS&T cores.

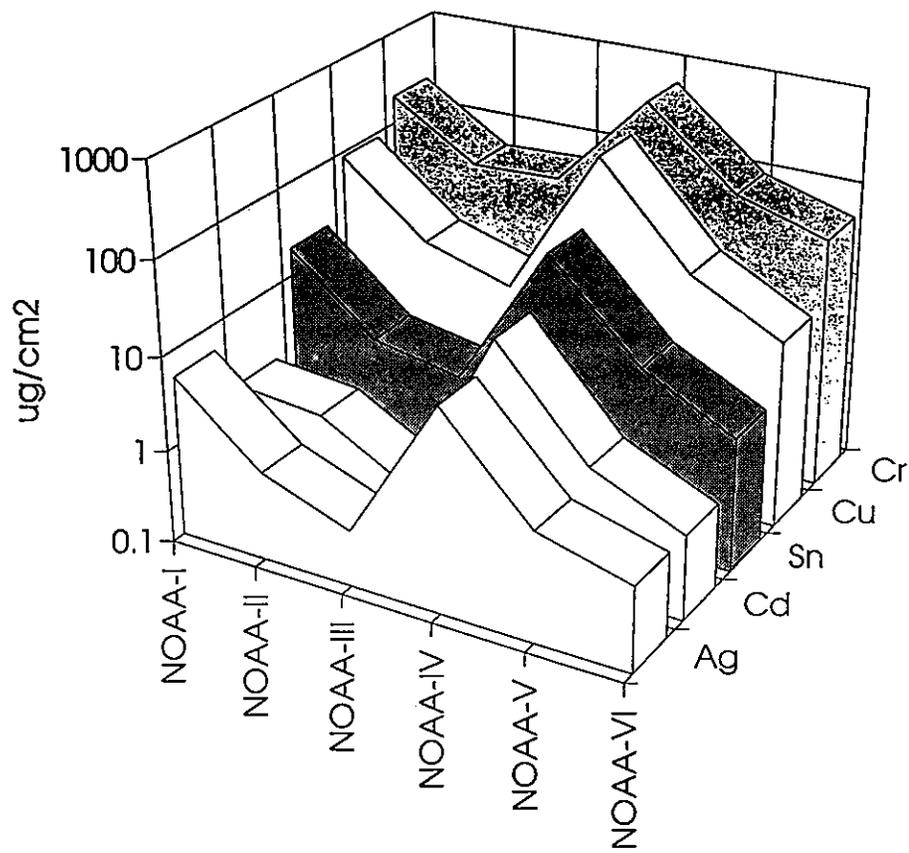


Figure 13. Variation of Ag, Cd, Sn, Cu and Cr inventories between NOAA NS&T cores.

multiplying the respective ratios by the standing stock of Cr in Palos Verdes Shelf sediments, 2289 metric tons (Huh *et al.*, 1990)). These are about 7%, 10% and 11% of the emission of Ag, Cd and Cu, respectively, from the JWPCP sewage outfall. (There is no emission data for Sn).

In deep Santa Monica-San Pedro Basin cores, inventory ratios of Ag/Cr, Cd/Cr, Sn/Cr and Cu/Cr average 0.017, 0.022, 0.07 and 0.28, respectively. Therefore, budgets of anthropogenic Ag, Cd, Sn and Cu in the basin floor are approximately 20, 30, 100 and 400 metric tons, respectively (calculated by multiplying the standing stock of Cr in the deep Santa Monica-San Pedro Basin, 1368 tons (Huh *et al.*, 1990), by the respective inventory ratios). The results suggest that, similar to Zn, these metals have higher mobility than Cr and that only approximately 2-3% of their total emission are trapped in the deep basin.

Although downcore distribution of Sb in the central Santa Monica Basin is similar to the metals discussed above (see Fig. 14), its spatial distribution is somewhat different. Downcore inventory of Sb in NOAA-I is even less than in NOAA-II, and in NOAA-IV it is only a factor of 2-3 higher than in the deep basin (NOAA-II and VI). This suggests that Sb is probably associated with very fine particles and can be more easily transported away. Downcore inventories of excess Sb in the deep Santa Monica Basin average $1.6 \mu\text{g}/\text{cm}^2$, yielding a Sb/Cr ratio of 0.035 and a budget of 48 tons of anthropogenic Sb in the deep basin floor. There is no historical emission data of Sb for comparison. We think Sb should behave like Cu, Zn and Cd and its standing stock in the deep basin probably also accounts for 2-3% of its total emission from sewage outfalls.

4. Distribution of non-pollutant metals

Distributions of other elements (Al, Si, Mn, Fe, Ni, As and Se) required for the NS&T Program are distinctly different from the above. Al and Si are the two most abundant elements in continental detritus; their distributions reflect the mineral composition of the matrix material. In the study region, near-shore sediments with a coarser grain size have slightly but obviously higher Al and Si concentrations than deep-basin sediments. In calculating the anthropogenic component of pollutant metals, Al is used as a "normalizer" to correct for their natural background levels. This normalization practice is especially important for deep-basin cores which showed a clear decrease of abiogenic material toward the sediment surface (see Figure 15), indicating remineralization of biogenic material following burial.

The distributions of Fe and As show diagenetic signals which are especially strong in deep-basin cores (Figs 16 and 17). The Fe enrichment near surface results from reduction of Fe in the sediments during the oxidation of organic matter (Froelich *et al.*, 1977), followed by upward diffusion and precipitation as amorphous oxyhydroxides near the sediment-water interface (Finney and Huh, 1989b). The smooth trend of Fe across a 19-year old turbidite layer at 2-6 cm in CaBS V-8 (Huh *et al.*, 1990) suggests that the diagenetic process is fast

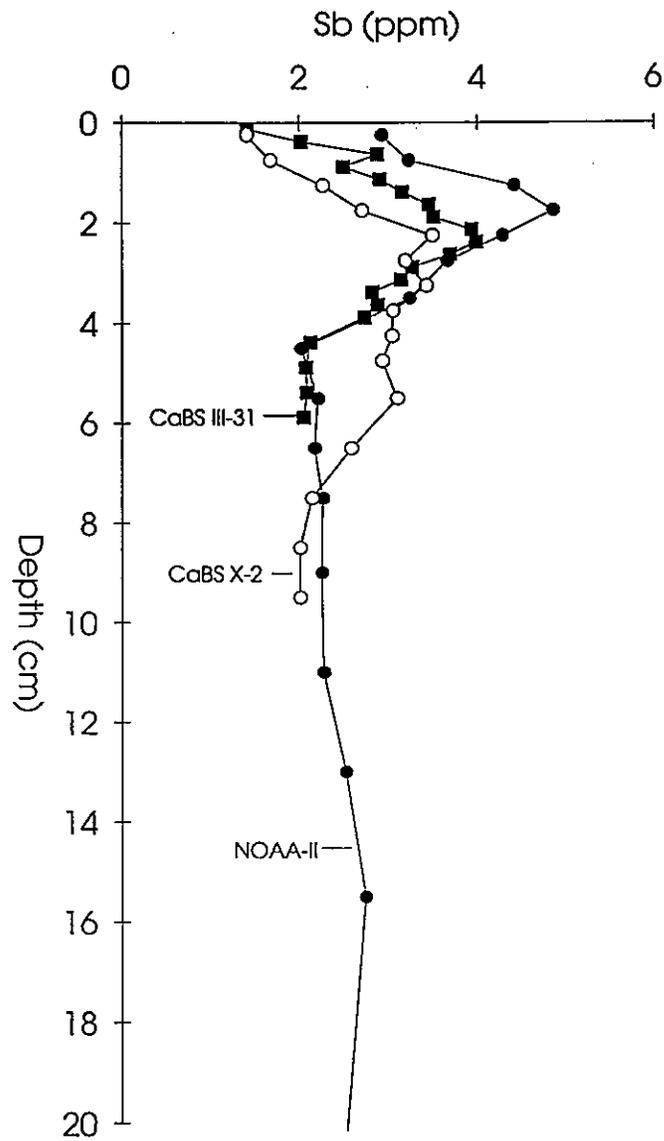


Figure 14. Profiles of Sb in deep basin cores: NOAA-II, CaBS III-31 and CaBS X-2.

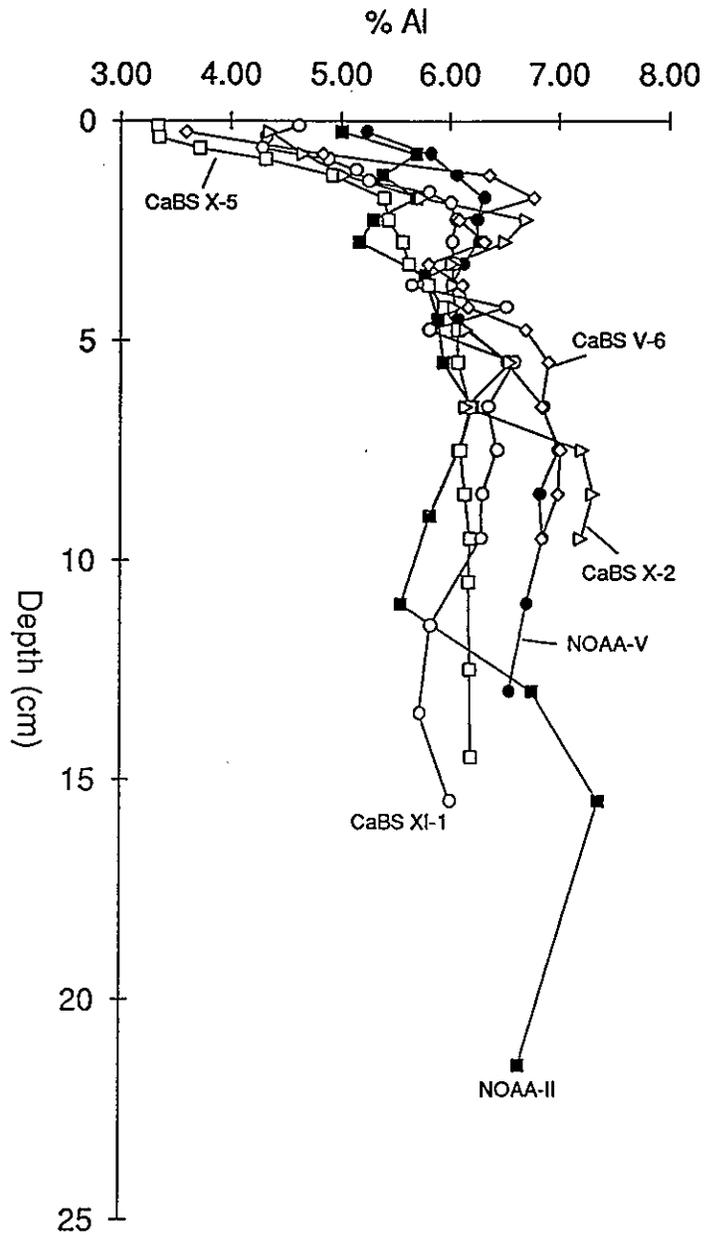


Figure 15. Profiles of Al in deep basin cores showing a pronounced increase with depth in the top ~2 cm.

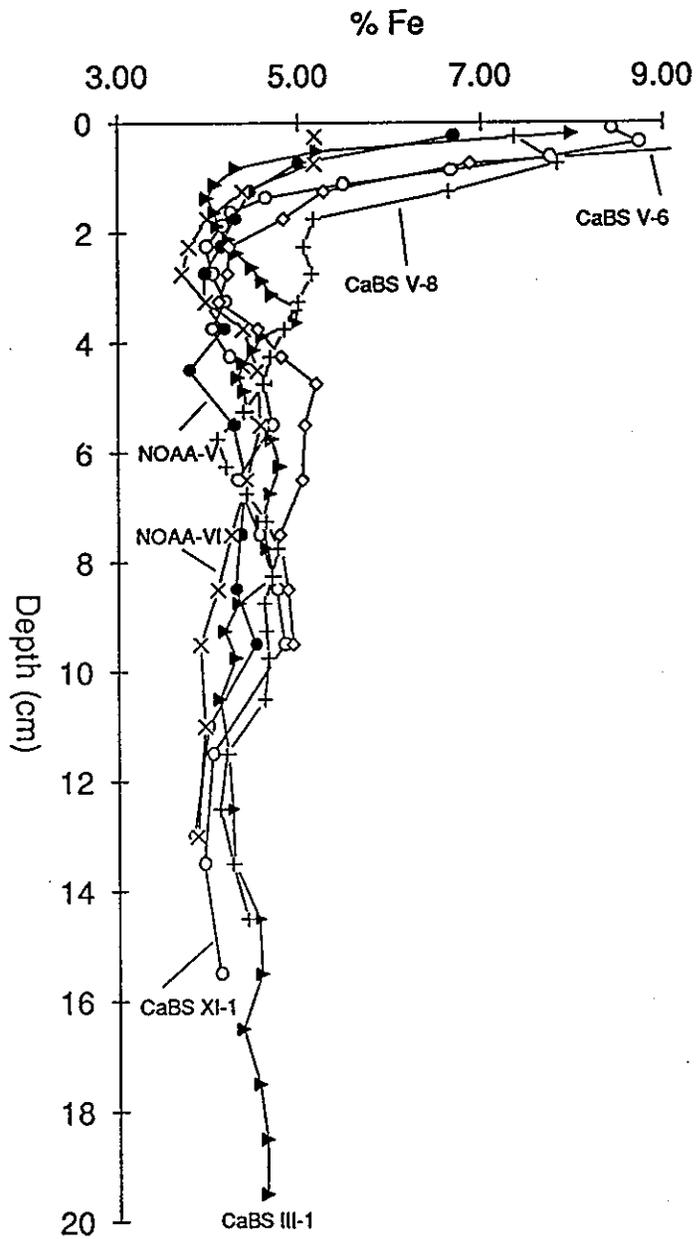


Figure 16. Profiles of Fe in deep basin cores showing a drastic decrease with depth in the top ~2 cm.

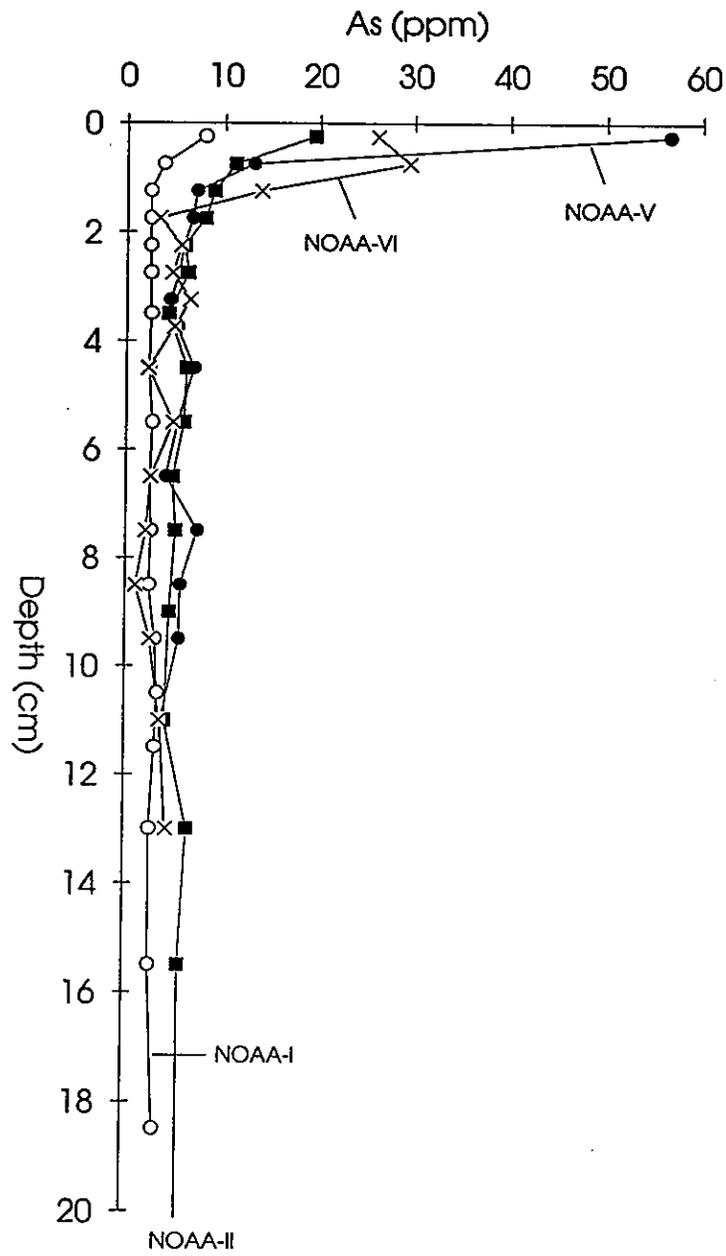


Figure 17 Profiles of As in deep basin cores: NOAA-I, NOAA-II, NOAA-V and NOAA-VI.

enough to erase primary deposition record of Fe at time scales probably from years to one or two decades. The surface enrichment of As, similar to that of P (Finney and Huh, 1989b), also appears to be diagenetically controlled. During early diagenesis, P is released near the sediment-water interface where it is probably adsorbed to the Fe-oxyhydroxides (Balistrieri and Murray, 1982; Dymond et al., 1984). Arsenic, being a chemical analog of P, is most likely involved in the same process.

The distributions of Mn, Ni and Se do not show any systematic pattern. Although the discharge of Ni from sewage outfalls is considerable and comparable in magnitude to Cr, Cu and Pb (see Fig. 11), the high mobility of sewage Ni results in a negligible anthropogenic component compared with the background Ni in sediments. The emission of Se is of the same magnitude as As and both are lower than the emission of Ag and Cd (SCCWRP, 1974-1990; Fig. 11). Among the elements exhibiting anthropogenic inputs, Ag and Cd show the lowest concentrations. Se is known to be a highly mobile, nutrient-type element. Furthermore, because the emission of Se does not exhibit a systematic trend (Fig. 11), it is unlikely that the deposition record of anthropogenic Se can be resolved.

5. Problems and Solutions

Mercury is one of the programmatically important metal required for the NS&T Program. Unfortunately, we have not been able to measure Hg in the sediment samples by ICP-MS due to very low signal-to noise ratio in the output. The emission of Hg from sewage outfalls is by far the lowest among all metals monitored by SCCWRP. It is as yet unclear to us whether our failure in measuring Hg is due to interference in the plasma or that the concentration of Hg in the samples is below detection limits. With a nominal Hg concentration on the order of 0.01-0.1 ppm in the Southern California Bight sediments and a dilution factor of ≈ 1000 during sample preparation, the concentration level of Hg in the sample solution would be on the order of 0.01-0.1 ppb, which, albeit extremely low, should still be well above the detection limit of Hg by ICP-MS (<1 ppt (parts per trillion), as given in the VG's promotion literature). After many additional analyses and studies, it became clearer why Hg was not detected by ICP-MS throughout the NS&T cores and it appears that isobaric interference by other ionic species in the plasma is most likely the cause.

Finally, some Hg data were obtained by neutron activation analysis. Only in one sediment core, NOAA-IV, can Hg be detected by the technique. It is important to point out that NOAA-IV is the core collected the closest (≈ 8 km) to the JWPCP sewage outfall. In core NOAA-IV, downcore profile of Hg is similar to those of other anthropogenic metals, with a subsurface maximum corresponding to time horizon of \approx circa 1970. The pre-1900 level of ≈ 0.05 ppm is in basic agreement with the baseline levels of 0.02-0.05 ppm reported by Galloway (1972) and 0.04-0.09 ppm reported by Chen and Lu (1974).

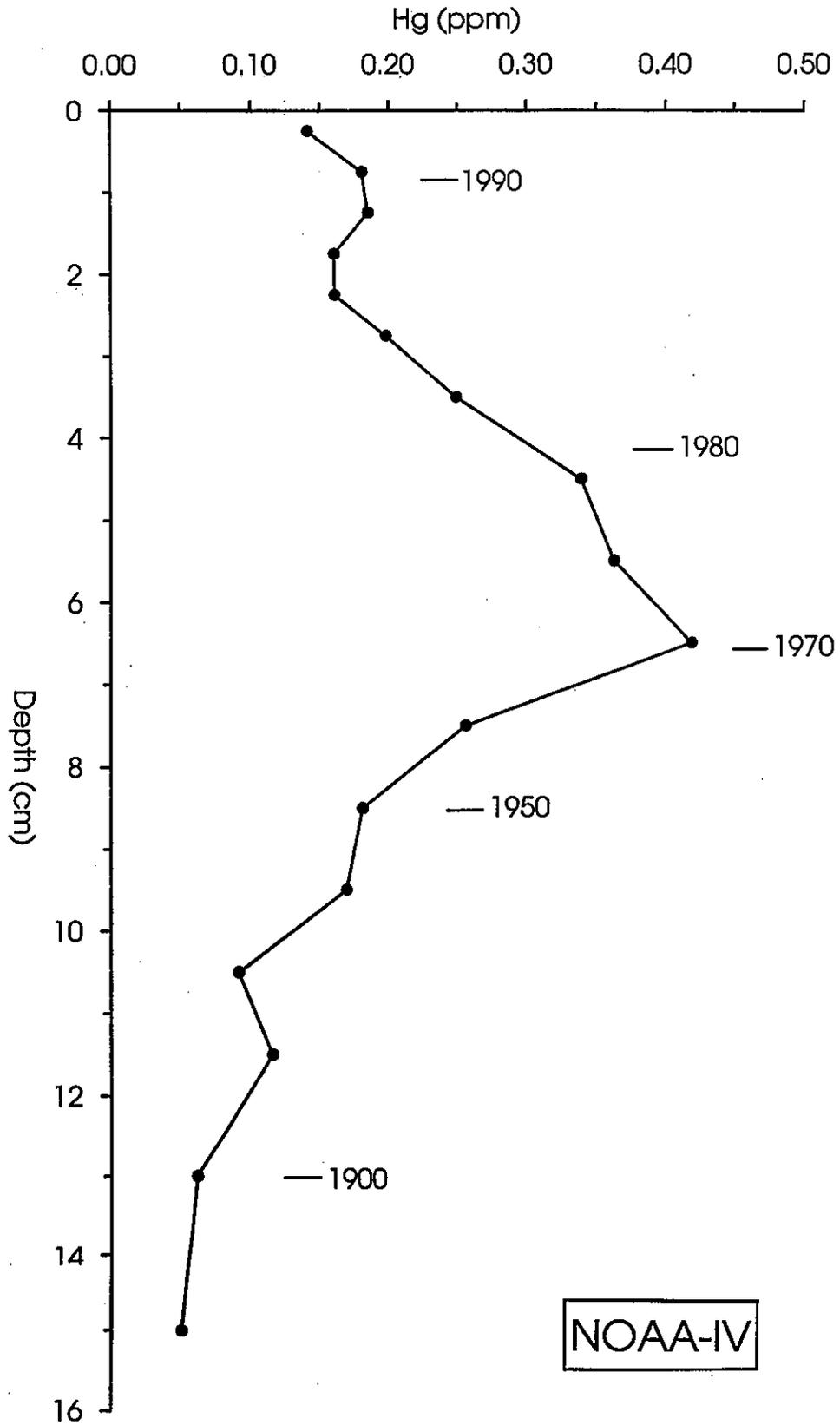


Figure 18. Profile of Hg in NOAA Core-IV.

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Table 1. Sediment cores used in this study

Core #	Latitude	Longitude	Water depth (m)	Time of collection
CaBS XI-1	33°45.54'N	118°50.88'W	904	Jan. 1990
CaBS XI-4	33°41.78'N	118°30.78'W	780	"
NOAA-I	33°51.00'N	118°38.00'W	593	Sept. 1991
NOAA-II	33°41.00'N	118°56.22'W	905	"
NOAA-III	33°36.01'N	118°40.48'W	585	"
NOAA-IV	33°41.67'N	118°22.78'W	457	"
NOAA-V	33°34.87'N	118°25.58'W	887	"
NOAA-VI	33°29.80'N	118°19.92'W	889	"

Table 2

NOAA-I (33°51.00'N, 118°38.00'W, water depth = 593 m)

Depth (cm)	Mid-depth (cm)	% H ₂ O	Cumulative mass (g/cm ²)	Pb-210 (dpm/g)	Pb-210ex (dpm/g)	Time of deposition* (A.D.)
0-0.5	0.25	67.51	0.0931	42.5	39.9 ± 0.5	1990.45
0.5-1	0.75	65.09	0.2890	43.9	41.4 ± 0.6	1987.85
1-1.5	1.25	65.38	0.4933	37.6	35.0 ± 0.6	1985.14
1.5-2	1.75	64.49	0.7000	35.2	32.6 ± 0.6	1982.40
2-2.5	2.25	63.53	0.9143	34.9	32.3 ± 0.6	1979.56
2.5-3	2.75	62.41	1.1373	35.2	32.6 ± 0.7	1976.60
3-4	3.5	60.10	1.4986	32.6	30.0 ± 0.6	1971.82
4-5	4.5	56.34	2.0276	29.0	26.4 ± 0.8	1964.80
5-6	5.5	55.20	2.6012	19.5	16.9 ± 0.6	1957.20
6-7	6.5	52.88	3.2079	17.1	14.6 ± 0.4	1949.16
7-8	7.5	51.63	3.8496	14.9	12.3 ± 0.3	1940.65
8-9	8.5	50.84	4.5116	12.2	9.58 ± 0.32	1931.88
9-10	9.5	48.72	5.2036	8.86	6.27 ± 0.31	1922.71
10-11	10.5	47.76	5.9279	8.56	5.97 ± 0.29	1913.10
11-12	11.5	47.89	6.6610	5.84	3.25 ± 0.19	1903.39
12-14	13	46.84	7.7813	4.00	1.41 ± 0.11	1888.54
14-17	15.5	45.68	9.7059	3.91	1.32 ± 0.11	1863.03
17-20	18.5	44.41	12.0889	2.59		1831.44

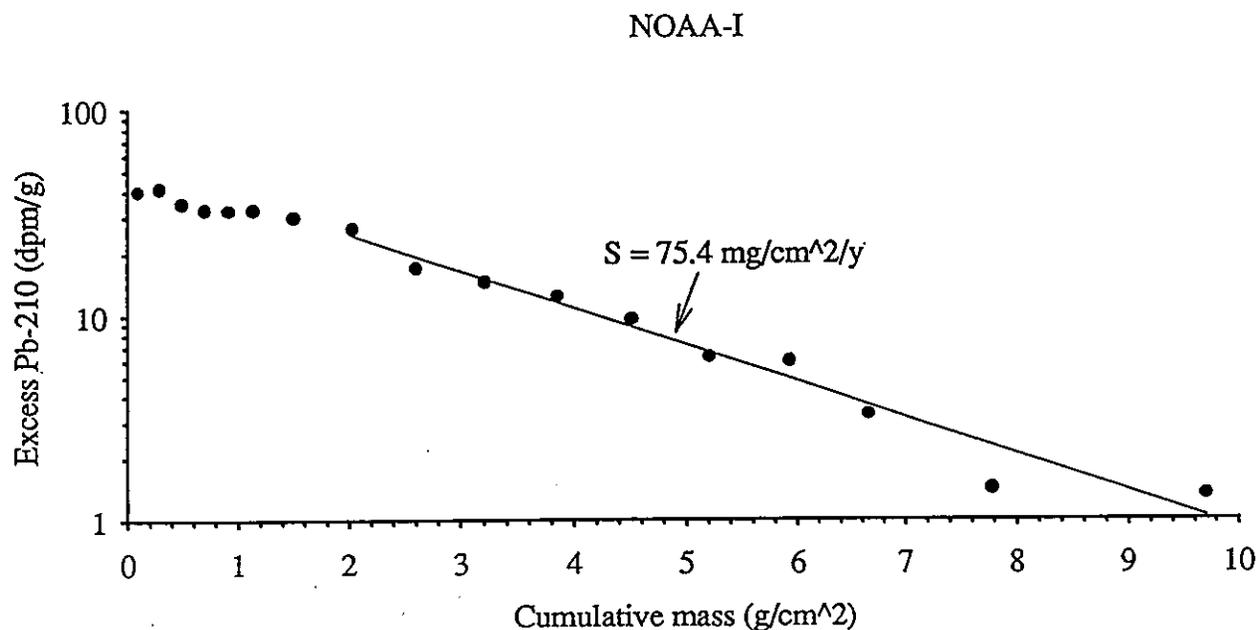
* Calculated using $S = 75.4 \text{ mg/cm}^2/\text{y}$ 

Table 3

NOAA-II (33°41.00'N, 118°56.22'W; water depth = 905 m)

Depth (cm)	Mid-depth (cm)	% H ₂ O	Cumulative mass (g/cm ²)	Pb-210 (dpm/g)	Pb-210ex (dpm/g)	Time of deposition (A.D.)
0-0.5	0.25	83.41	0.0376	128.8	123.7 ± 1.2	1989.72
0.5-1	0.75	77.81	0.1309	110.9	105.7 ± 1.1	1984.86
1-1.5	1.25	76.33	0.2474	95.3	90.1 ± 1.3	1978.79
1.5-2	1.75	75.76	0.3709	80.7	75.6 ± 1.1	1972.35
2-2.5	2.25	75.60	0.4970	76.8	71.6 ± 1.1	1965.78
2.5-3	2.75	73.95	0.6294	58.2	53.1 ± 1.0	1958.88
3-4	3.5	73.23	0.8418	40.7	35.6 ± 0.8	1947.81
4-5	4.5	72.39	1.1347	26.4	21.3 ± 0.4	1932.54
5-6	5.5	72.43	1.4333	19.7	14.5 ± 0.4	1916.98
6-7	6.5	70.57	1.7452	12.5	7.33 ± 0.30	1900.73
7-8	7.5	69.50	2.0790	11.6	6.45 ± 0.27	1894.39
8-10	9	70.41	2.5780	9.50	4.34 ± 0.19	1884.92
10-12	11	69.15	3.2533	8.26	3.10 ± 0.15	1872.11
12-14	13	61.69	4.0680	5.13		1856.65
14-17	15.5	41.74	5.8421	2.54		1822.98
17-20	18.5	34.41	8.7381	5.27		1768.02

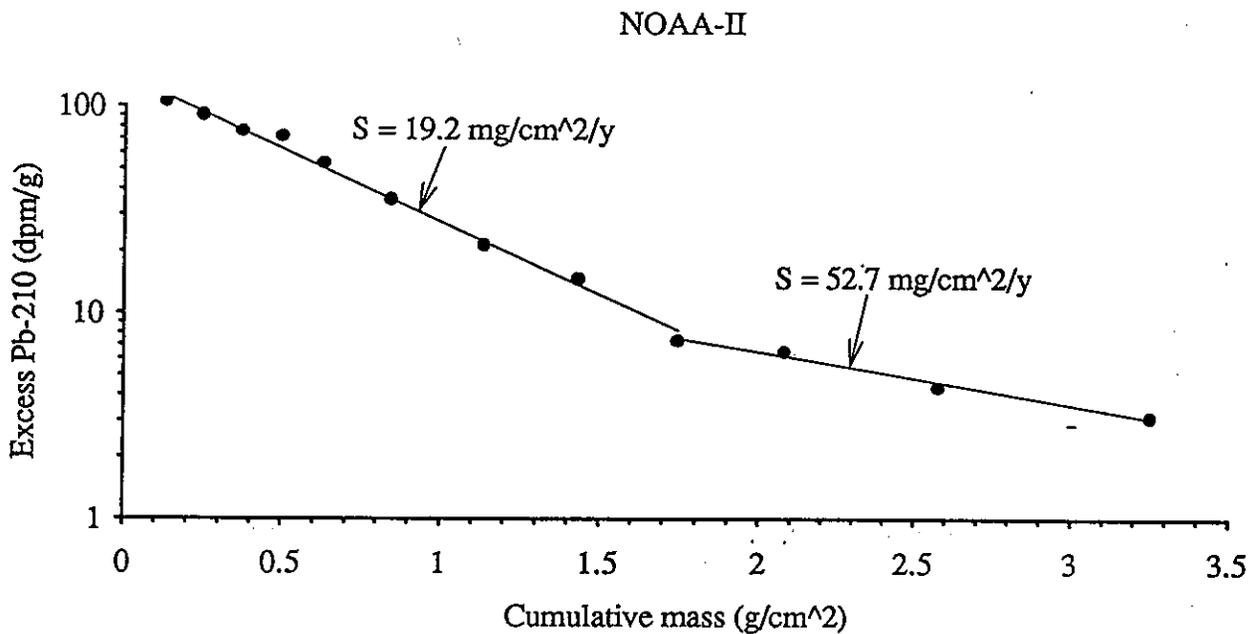


Table 4

NOAA-III (33°36.01'N, 118°40.48'W; water depth = 585 m)

Depth (cm)	Mid-depth (cm)	% H ₂ O	Cumulative mass (g/cm ²)	Pb-210 (dpm/g)	Pb-210ex (dpm/g)	Time of deposition* (A.D.)
0-0.5	0.25	69.34	0.0861	21.5	18.1 ± 0.4	1990.36
0.5-1	0.75	60.48	0.2942	19.6	16.2 ± 0.4	1987.17
1-1.5	1.25	59.31	0.5436	19.3	15.9 ± 0.4	1983.35
1.5-2	1.75	57.54	0.8060	19.6	16.2 ± 0.4	1979.33
2-2.5	2.25	58.52	1.0720	19.1	15.8 ± 0.5	1975.25
2.5-3	2.75	57.10	1.3400	18.2	14.8 ± 0.5	1971.14
3-4.	3.5	56.63	1.7559	15.9	12.5 ± 0.4	1964.76
4-5.	4.5	56.30	2.3165	14.5	11.1 ± 0.3	1956.17
5-6.	5.5	56.12	2.8819	12.3	8.86 ± 0.30	1947.51
6-7.	6.5	54.74	3.4619	9.89	6.50 ± 0.25	1938.62
7-8.	7.5	54.41	4.0582	8.12	4.73 ± 0.20	1929.48
8-10.	9	54.55	4.9545	7.25	3.86 ± 0.19	1915.74
10-12.	11	52.22	6.1933	5.01	1.62 ± 0.11	1896.75
12-14.	13	49.33	7.5366	3.88		1876.16
14-17	15.5	50.81	9.2436	3.60		1849.99
17-20	18.5	50.40	11.2682	3.41		1818.96

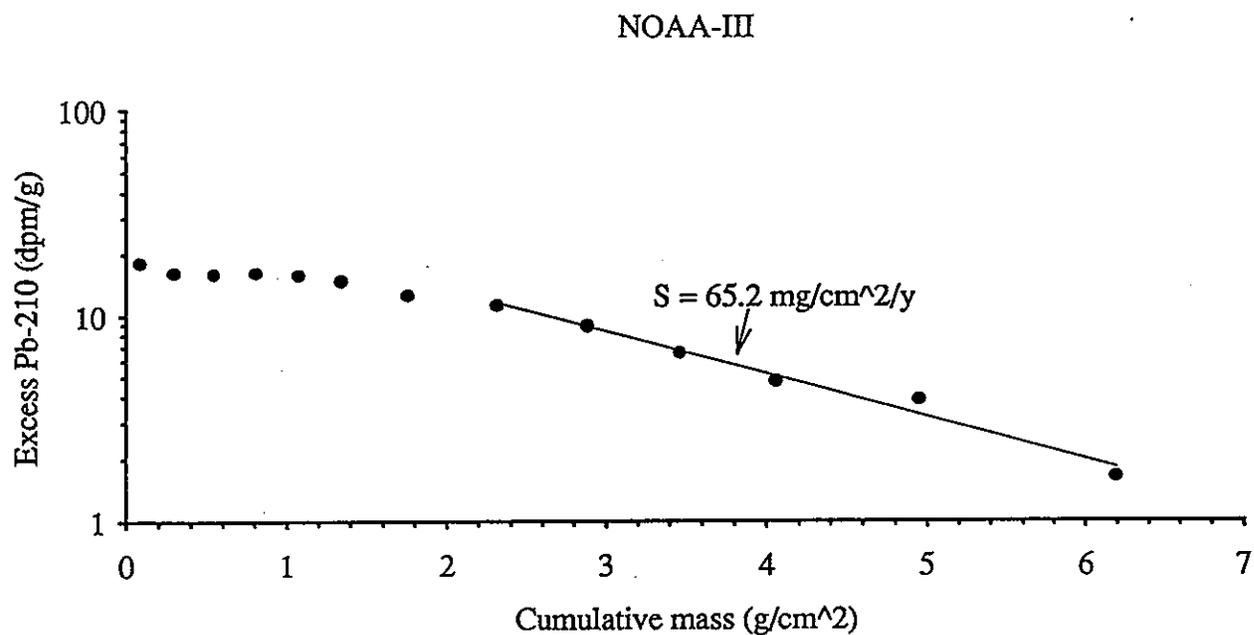
* Calculated using $S = 65.2 \text{ mg/cm}^2/\text{y}$.

Table 5

NOAA-IV (33°41.67'N, 118°22.78'W; water depth = 457 m)

Depth (cm)	Mid-depth (cm)	% H ₂ O	Cumulative mass (g/cm ²)	Pb-210 (dpm/g)	Pb-210ex (dpm/g)	Time of deposition (A.D.)
0-0.5	0.25	73.98	0.0690	41.9	37.8 ± 0.5	1991.26
0.5-1	0.75	63.45	0.2475	39.6	35.5 ± 0.5	1990.18
1-1.5	1.25	61.81	0.4733	38.1	34.0 ± 0.5	1988.80
1.5-2	1.75	61.08	0.7092	38.1	34.0 ± 0.4	1987.37
2-2.5	2.25	60.34	0.9514	38.4	34.3 ± 0.5	1985.90
2.5-3	2.75	59.93	1.1987	36.3	32.2 ± 0.5	1984.39
3-4	3.5	57.08	1.5978	32.9	28.8 ± 0.5	1981.97
4-5	4.5	53.90	2.1770	28.5	24.4 ± 0.5	1978.45
5-6	5.5	51.44	2.8106	27.0	22.9 ± 0.4	1974.60
6-7	6.5	49.63	3.4870	25.4	21.3 ± 0.4	1970.49
7-8	7.5	47.17	4.2081	18.9	14.8 ± 0.4	1960.48
8-9	8.5	46.25	4.9654	14.7	10.6 ± 0.3	1949.97
9-10	9.5	44.99	5.7468	10.1	6.02 ± 0.27	1939.13
10-11	10.5	44.36	6.5496	9.95	5.86 ± 0.23	1927.99
11-12	11.5	43.79	7.3660	6.12	2.03 ± 0.12	1916.67
12-14	13	41.85	8.6460	6.44	2.35 ± 0.12	1898.91
14-16	15	40.73	10.4101	4.12		1874.43
16-19	17.5	41.5	12.6209	4.06		1843.75

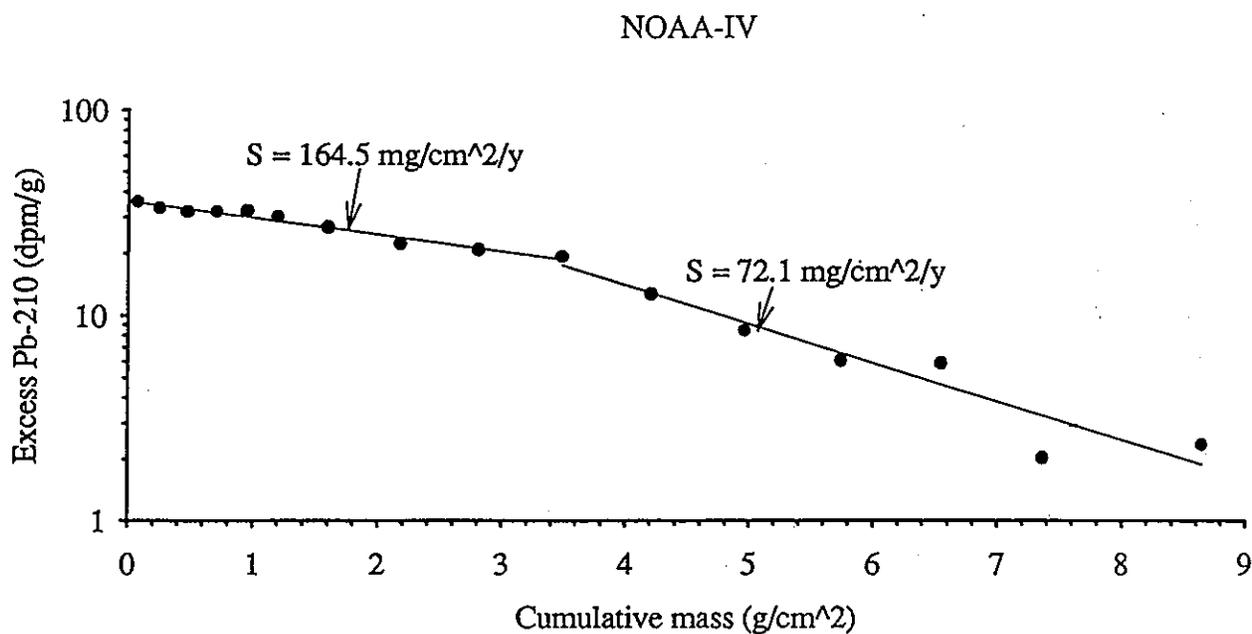


Table 6

NOAA-V (33°34.87'N, 118°25.58'W; water depth = 887 m)

Depth (cm)	Mid-depth (cm)	% H ₂ O	Cumulative mass (g/cm ²)	Pb-210 (dpm/g)	Pb-210ex (dpm/g)	Time of deposition (A.D.)
0-0.5	0.25	86.71	0.0275	107.6	100.7 ± 1.4	1990.88
0.5-1	0.75	79.11	0.1064	107.0	100.2 ± 1.3	1988.59
1-1.5	1.25	75.57	0.2212	94.8	87.9 ± 1.6	1985.25
1.5-2	1.75	74.26	0.3526	87.2	80.4 ± 1.4	1981.43
2-2.5	2.25	74.44	0.4880	74.0	67.1 ± 1.2	1977.49
2.5-3	2.75	74.16	0.6238	62.2	55.4 ± 1.2	1973.54
3-3.5	3.25	74.64	0.7588	62.4	55.6 ± 1.3	1969.62
3.5-4	3.75	73.92	0.8947	57.0	50.2 ± 1.0	1965.66
4-5	4.5	74.58	1.0977	45.0	38.2 ± 0.7	1959.76
5-6	5.5	71.80	1.3852	28.6	21.8 ± 0.5	1942.10
6-7	6.5	70.98	1.6988	18.6	11.8 ± 0.3	1922.83
7-8	7.5	68.87	2.0343	13.6	6.77 ± 0.24	1902.23
8-9	8.5	67.63	2.3953	10.2	3.36 ± 0.15	1880.05
9-10	9.5	66.16	2.7775	8.28	1.43 ± 0.07	1856.58
10-12	11	65.67	3.3760	6.80		1819.81
12-14	13	64.96	4.1907	6.90		1769.76

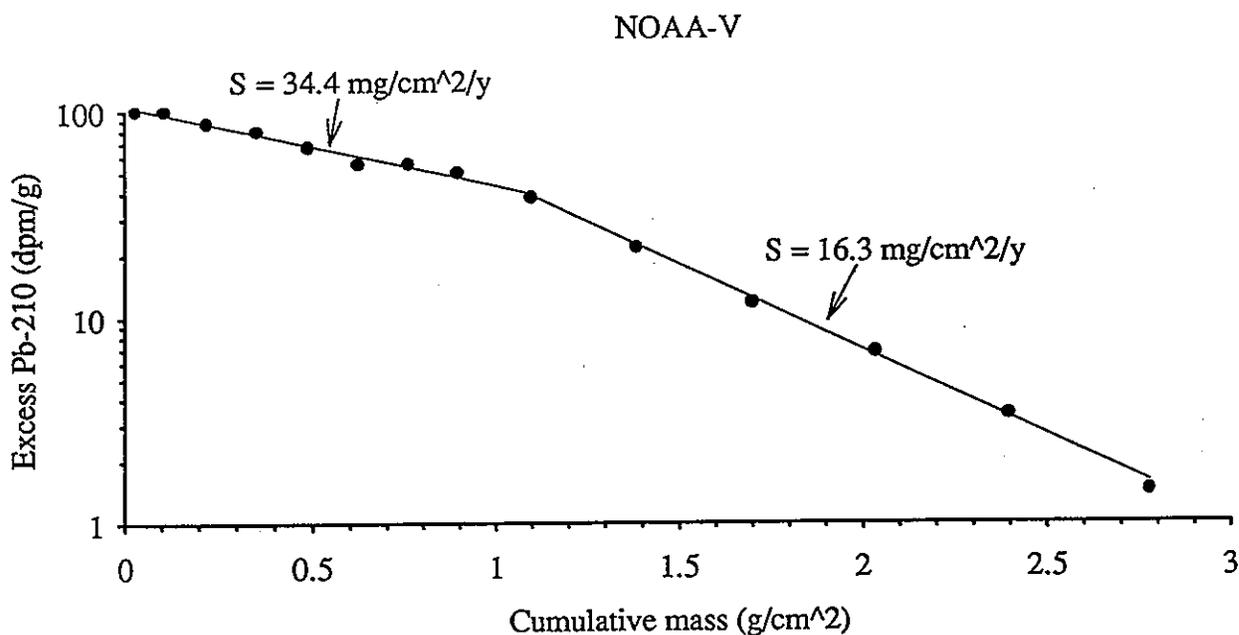


Table 7

NOAA-VI (33°29.80'N, 118°19.92'W; water depth = 889 m)

Depth (cm)	Mid-depth (cm)	% H ₂ O	Cumulative mass Pb-210 (g/cm ²)	Pb-210 (dpm/g)	Pb-210ex (dpm/g)	Time of deposition* (A.D.)
0-0.5	0.25	81.49	0.0437	76.39	67.5 ± 1.0	1987.13
0.5-1	0.75	76.13	0.1488	74.42	65.5 ± 1.1	1983.60
1-1.5	1.25	66.16	0.3087	52.42	43.2 ± 1.0	1980.00
1.5-2	1.75	71.27	0.4860	65.25	56.2 ± 1.0	1977.70
2-2.5	2.25	73.68	0.6349	81.03	72.2 ± 1.4	1975.43
2.5-3	2.75	73.67	0.7750	62.48	53.4 ± 1.1	1960.79
3-3.5	3.25	72.99	0.9177	41.34	32.0 ± 0.8	1945.89
3.5-4	3.75	71.48	1.0683	29.56	20.1 ± 0.5	1930.17
4-5	4.5	71.01	1.3059	18.18	8.58 ± 0.31	1905.36
5-6	5.5	69.80	1.6341	14.98	5.34 ± 0.18	1888.57
6-7	6.5	68.86	1.9786	13.34	3.68 ± 0.11	1870.95
7-8	7.5	67.88	2.3377	11.50	1.82 ± 0.06	1852.58
8-9	8.5	66.87	2.7123	9.73		1833.42
9-10	9.5	59.87	3.1531	10.37		1810.87

* Ages in the top 2 cm can not be dated by Pb-210 due to the presence of a turbidite layer (centered in 1-1.5 cm) deposited in the winter of 1979-80 (Huh et al., 1990); they are estimated from interpolation by assuming time of deposition (A.D.) = 1991.68 at zero depth and 1980 at 1.25 cm.

Time of deposition below the turbidite layer is calculated using 120 dpm/g, the highest excess Pb-210 observed in the San Pedro Basin (Huh et al., 1990), as the initial (i.e. zero-time) concentration.

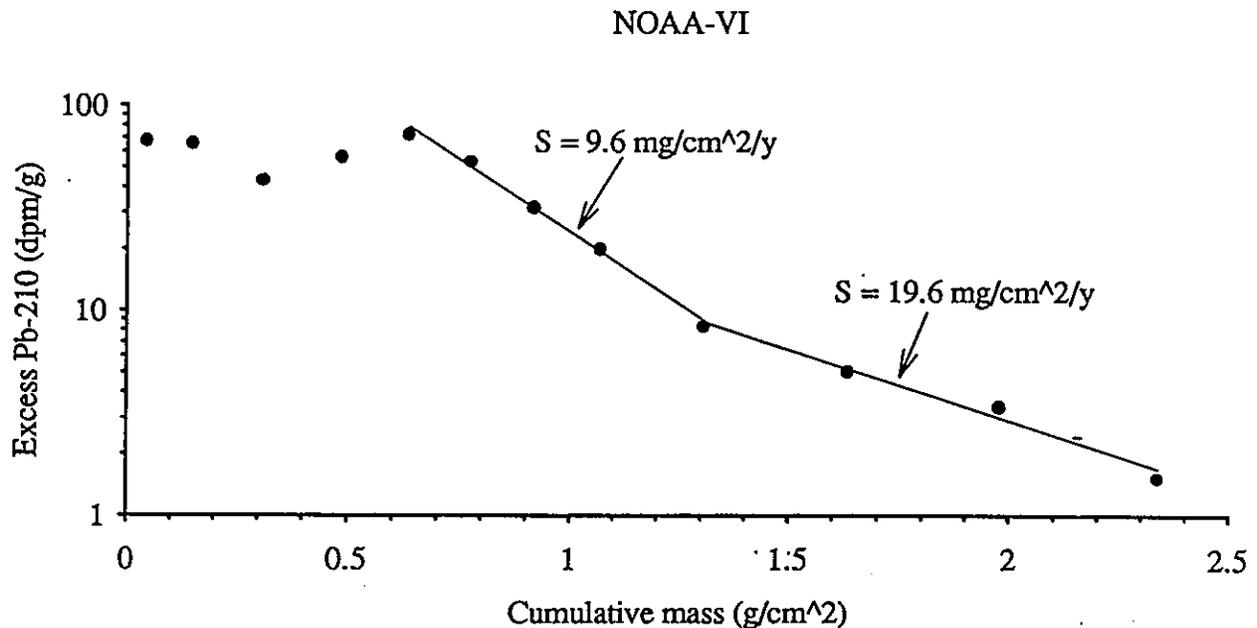


Table 8

CaBS XI-1 (33°45.54'N, 118°50.88'W; water depth = 904 m)

Depth (cm)	Mid-depth (cm)	% H ₂ O	Cumulative mass (g/cm ²)	Pb-210 (dpm/g)	Pb-210ex (dpm/g)	Time of deposition (A.D.)
0-0.25	0.125	87.70	0.0123	109.3	100.8 ± 0.5	1989.32
0.25-0.5	0.375	87.41	0.0373	102.5	94.0 ± 0.6	1987.79
0.5-0.75	0.625	87.38	0.0627	110.4	101.9 ± 0.6	1986.24
0.75-1	0.875	85.64	0.0909	118.0	109.5 ± 0.6	1984.51
1-1.25	1.125	84.88	0.1227	126.9	118.4 ± 0.6	1982.56
1.25-1.5	1.375	83.74	0.1575	131.5	123.0 ± 0.7	1980.43
1.5-1.75	1.625	81.70	0.1973	135.2	126.7 ± 0.6	1978.00
1.75-2	1.875	79.36	0.2441	131.8	123.3 ± 0.8	1975.13
2-2.5	2.25	77.78	0.3252	116.0	107.5 ± 0.6	1970.16
2.5-3	2.75	78.04	0.4360	103.0	94.5 ± 0.4	1963.38
3-3.5	3.25	77.22	0.5487	90.4	81.9 ± 0.3	1956.47
3.5-4	3.75	76.02	0.6683	74.6	66.1 ± 0.3	1949.15
4-4.5	4.25	72.47	0.8046	40.0	31.5 ± 0.3	1940.81
4.5-5	4.75	71.06	0.9586	52.3	43.8 ± 0.3	1931.37
5-6	5.5	71.80	1.1920	31.7	23.2 ± 0.2	1917.08
6-7	6.5	69.92	1.5135	20.4	11.9 ± 0.11	1897.40
7-8	7.5	68.64	1.8587	13.9	5.39 ± 0.11	1876.26
8-9	8.5	69.40	2.2078	11.4	2.89	1854.88
9-10	9.5	71.24	2.5373	10.8	2.29	1840.25
11-12	11.5	69.95	3.0302	9.54	1.03	1818.36
13-14	13.5	70.10	3.6979	8.90	0.39	1788.71
15-16	15.5	70.32	4.3601	8.51		1759.31

CaBS XI-1

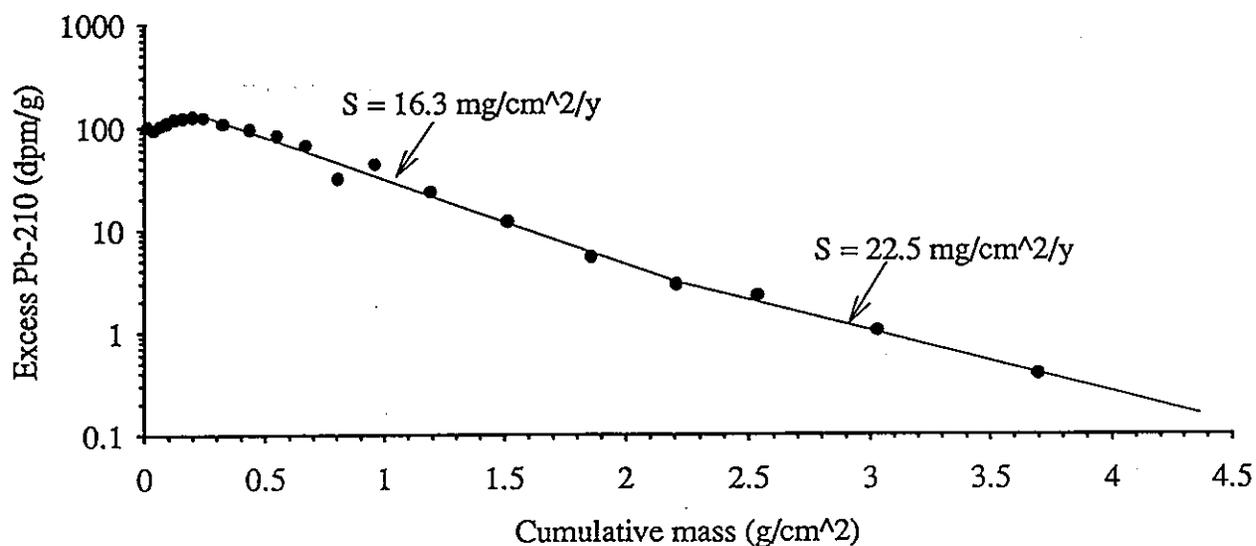


Table 9

XI-4 (33°41.78'N, 118°30.78'W; water depth =780 m)

Depth (cm)	Mid-depth (cm)	% H ₂ O	Cumulative mass (g/cm ²)	Pb-210 (dpm/g)	Pb-210ex (dpm/g)	Time of deposition (A.D.)
0-0.5	0.25	86.25	0.0289	77.3	67.6 ± 0.4	1988.70
0.5-1	0.75	82.31	0.0988	68.8	59.1 ± 0.4	1985.35
1-1.5	1.25	79.33	0.1905	67.4	57.7 ± 0.4	1980.97
1.5-2	1.75	77.09	0.2994	60.7	51.1 ± 0.3	1975.76
2-2.5	2.25	75.32	0.4218	65.9	56.2 ± 0.3	1969.90
2.5-3	2.75	74.13	0.5546	64.4	54.7 ± 0.3	1963.56
3-3.5	3.25	72.50	0.6974	70.2	60.5 ± 0.4	1956.73
3.5-4	3.75	71.73	0.8488	64.0	54.4 ± 0.4	1949.49
4-4.75	4.375	69.81	1.0524	51.7	42.0 ± 0.3	1939.75
4.75-5	4.875	67.61	1.2252	40.8	31.1 ± 0.3	1931.49
5-6.	5.5	65.49	1.4738	31.6	21.9 ± 0.3	1919.60
6-7.	6.5	64.70	1.8847	23.7	14.0 ± 0.3	1899.95
7-8.	7.5	65.00	2.2996	16.8	7.1 ± 0.1	1880.11
8-9.	8.5	64.32	2.7753	14.6	4.9 ± 0.1	1857.36
9-10.	9.5	63.47	3.1481			1839.54
10-11.	10.5	62.94	3.5901			1818.40
11-12.	11.5	61.81	4.0460	9.69		1796.60

CaBS XI-4

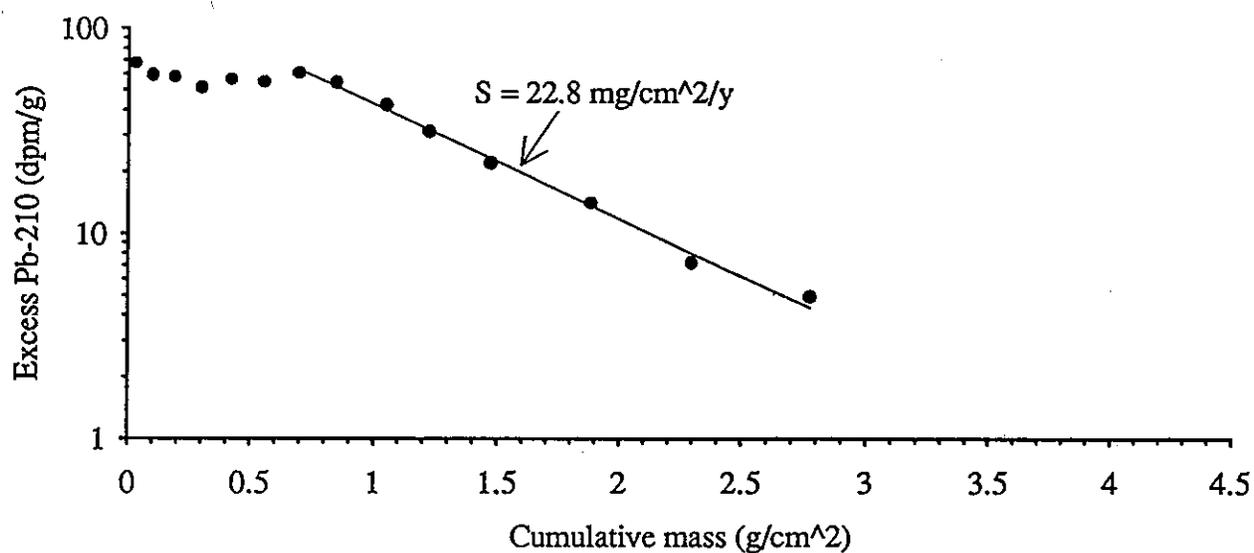


Table 10. Calibration results for Sediment R

	Accepted value	Number of results	Number of rejections	OSU data*	
				Mean	Std. dev.
Al (%)	2.19 ± 0.44	22	6	2.075 ± 0.003	
Cr (ppm)	37.5 ± 12.3	29	9	31.4 ± 0.9	
Mn (ppm)	217 ± 50	24	8	242 ± 2	
Fe (%)	1.88 ± 0.25	27	6	1.96 ± 0.01	
Ni (ppm)	20.6 ± 2.9	27	3	28.9 ± 0.5	
Cu (ppm)	9.81 ± 1.84	31	6	8.66 ± 0.21	
Zn (ppm)	44.2 ± 10.8	31	4	49.1 ± 1.5	
Ag (ppm)	0.040 ± 0.022	16	5	0.042 ± 0.006	
Cd (ppm)	0.138 ± 0.051	27	5	0.173 ± 0.009	
Pb (ppm)	10.4 ± 5.1	27	2	7.9 ± 0.3	

* Based on five replicates

Table 11. NOAA-1 (33°51.00'N, 118°38.00'W; water depth = 593 m)

Mid-depth (cm)	Cumulative mass (g/cm ²)	Time of deposition (A.D.)	Al %	Si %	Cr ppm	Mn ppm	Fe %	Ni ppm	Cu ppm	Zn ppm	Ag ppm	Cd ppm	Ba ppm	Pb ppm	As ppm	Se ppm	Sn ppm	Sb ppm
0.25	0.0931	1990.45	6.23	22.8	133	383	3.55	55.2	46.7	147	1.65	1.19	794	23.4	7.9	29	7.55	1.10
0.75	0.2890	1987.85	6.25	23.6	125	374	3.39	54.2	46.3	143	1.74	1.25	814	25.1	3.7	26	8.50	1.14
1.25	0.4933	1985.14	6.41	23.9	133	403	3.50	56.2	50.5	151	1.74	1.20	846	24.7	2.4	25	8.34	1.20
1.75	0.7000	1982.40	6.51	24.0	141	408	3.52	56.3	50.6	150	1.71	1.24	803	23.2	2.4	24	10.2	1.23
2.25	0.9143	1979.56	6.39	23.3	128	396	3.50	54.9	52.2	168	1.79	1.28	792	23.4	2.4	23	9.65	1.26
2.75	1.1373	1976.60	6.42	23.9	138	403	3.54	56.7	52.0	162	1.86	1.37	811	25.4	2.4	26	8.09	1.28
3.5	1.4986	1971.82	6.51	24.2	133	403	3.50	57.5	52.2	166	1.75	1.30	857	26.2	2.5	34	8.94	1.26
4.5	2.0276	1964.80	6.44	23.5	125	396	3.34	52.4	48.5	169	1.68	1.38	844	24.6	2.3	34	7.23	1.21
5.5	2.6012	1957.20	6.57	24.7	114	419	3.40	50.9	41.6	159	1.34	1.36	837	23.7	2.7	34	5.67	1.18
6.5	3.2079	1949.16	6.62	23.9	102	420	3.26	51.3	35.3	135	1.04	1.24	854	19.7	2.5	26	3.52	1.13
7.5	3.8496	1940.65	6.67	25.2	93	348	3.40	53.2	32.3	143	0.74	1.12	831	17.2	2.6	8	2.58	1.13
8.5	4.5116	1931.88	6.79	25.8	87	424	3.44	52.9	29.8	139	0.55	1.00	848	15.4	2.4	28	1.88	1.15
9.5	5.2036	1922.71	6.72	25.5	84	431	3.46	57.8	27.3	135	0.40	0.95	817	12.7	3.0	29	1.60	1.09
10.5	5.9279	1913.10	6.59	24.2	82	429	3.44	55.9	27.2	139	0.39	0.96	807	12.1	3.3	27	1.31	1.06
11.5	6.6610	1903.39	6.71	24.5	72	431	3.37	58.2	26.0	144	0.22	0.87	805	10.3	3.1	25	1.34	1.10
13	7.7813	1888.54	6.67	25.4	73	433	3.38	53.6	22.7	119	0.15	0.84	819	9.0	2.6	22	1.34	1.08
15.5	9.7059	1863.03	6.57	25.5	72	421	3.31	53.0	23.1	119	0.18	0.91	774	9.3	2.6	23	1.31	1.00
18.5	12.0889	1831.44	6.54	25.6	72	416	3.27	53.5	22.3	129	0.15	0.95	792	8.8	3.2	22	1.31	1.07

Table 12. NOAA-II (33°41.00'N, 118°56.22'W; water depth = 905 m) Table 12.

Mid-depth (cm)	Cumulative mass (g/cm ²)	Time of deposition (A.D.)	Al %	Si %	Cr ppm	Mn ppm	Fe %	Ni ppm	Cu ppm	Zn ppm	Ag ppm	Cd ppm	Ba ppm	Pb ppm	As ppm	Se ppm	Sn ppm	Sb ppm
0.25	0.0376	1989.72	5.00	17.0	137	308	4.12	102	49.7	135	1.36	2.63	947	19.0	19.5	25	4.97	2.92
0.75	0.1309	1984.86	5.69	17.4	143	330	3.96	108	50.4	164	1.21	1.96	867	24.8	11.1	30	6.00	3.22
1.25	0.2474	1978.79	5.37	16.6	160	301	3.68	99	55.7	178	1.59	2.89	979	27.4	8.9	30	7.00	4.41
1.75	0.3709	1972.35	5.69	18.0	173	301	4.02	108	54.3	181	1.62	2.85	933	28.9	8.0	30	8.09	4.85
2.25	0.4970	1965.78	5.29	16.8	155	282	3.62	96	96.0	174	1.80	3.47	1056	26.8	5.8	20	4.63	4.28
2.75	0.6294	1958.88	5.16	16.9	134	305	4.08	104	46.5	154	1.33	2.35	932	21.5	6.3	29	3.60	3.66
3.5	0.8418	1947.81	5.77	17.3	120	336	4.47	92	41.7	161	0.83	1.56	830	17.8	4.3	36	3.05	3.23
4.5	1.1347	1932.54	5.89	19.1	102	338	4.22	90	39.7	145	0.52	1.03	836	13.7	6.1	29	1.74	2.02
5.5	1.4333	1916.98	5.94	19.3	100	339	4.05	89	39.0	135	0.46	1.27	836	10.8	5.9	12	2.05	2.20
6.5	1.7452	1900.73	6.20	20.4	101	348	4.24	90	38.3	135	0.36	1.30	878	10.3	4.8	52	1.77	2.16
7.5	2.0790	1894.39	6.08	19.0	99	344	4.20	83	37.5	136	0.41	1.21	889	10.0	5.1	35	1.82	2.25
9	2.5780	1884.92	5.82	18.8	104	336	4.00	88	38.1	135	0.43	1.01	913	9.4	4.5	46	1.74	2.24
11	3.2533	1872.11	5.55	18.9	105	325	3.69	92	37.5	132	0.46	1.57	930	8.3	4.1	52	1.90	2.26
13	4.0680	1856.65	6.75	24.0	82	348	3.91	68	35.4	125	0.26	1.19	732	11.2	6.4	34	1.91	2.50
15.5	5.8421	1822.98	7.35	30.3	54	348	3.14	39	22.0	95	0.08	0.88	704	13.0	5.6	43	1.80	2.72
21.5	8.7381	1768.02	6.62	21.7	80	335	4.18	65	32.2	122	0.30	0.93	755	11.3	5.7	38	1.92	2.45

Table 13. NOAA-III (33°36.01'N, 118°40.48'W; water depth = 585 m)

Mid-depth (cm)	Cumulative mass (g/cm ²)	Time of deposition (A.D.)	Al %	Si %	Cr ppm	Mn ppm	Fe %	Ni ppm	Cu ppm	Zn ppm	Ag ppm	Cd ppm	Ba ppm	Pb ppm	As ppm	Se ppm	Sn ppm	Sb ppm
0.25	0.0861	1990.36	5.14	22.5	186.8	308	7.13	78.6	32.6	162	0.25	0.81	543	10.6	12.5	14	2.48	3.19
0.75	0.2942	1987.17	5.47	20.9	164.4	369	5.62	90.7	39.4	206	0.32	0.73	638	10.9	12.1	13	1.89	1.88
1.25	0.5436	1983.35	5.49	22.0	170.9	364	5.67	84.4	37.5	168	0.30	0.82	608	10.6	10.6	13	1.58	2.17
1.75	0.8060	1979.33	5.47	22.6	178.3	353	5.80	88.8	37.4	170	0.29	0.80	602	10.5	8.4	11	1.56	1.86
2.25	1.0720	1975.25	5.40	21.4	176.9	347	5.75	92.5	37.5	164	0.30	0.86	608	11.1	11.8	13	1.55	1.94
2.75	1.3400	1971.14	5.41	22.8	178.2	343	6.15	90.7	36.7	158	0.28	0.78	601	10.7	12.0	14	1.59	2.24
3.5	1.7559	1964.76	5.49	20.9	172.1	352	5.88	85.8	39.2	165	0.30	0.76	621	10.4	10.2	11	1.56	2.01
4.5	2.3165	1956.17	5.55	22.2	168.7	369	5.43	96.5	36.4	168	0.30	0.82	644	10.7	8.8	13	1.50	1.98
5.5	2.8819	1947.51	5.65	22.9	166.8	366	5.70	99.4	36.5	153	0.25	0.84	655	9.9	9.7	13	1.71	2.06
6.5	3.4619	1938.62	5.63	22.0	158	365	5.42	88.8	35.5	161	0.20	0.93	609	8.9	9.6	11	1.05	1.92
7.5	4.0582	1929.48	5.52	22.8	159	359	5.35	87.9	36.2	153	0.17	0.84	590	8.3	9.0	14	1.05	1.89
9	4.9545	1915.74	5.55	21.5	157.6	335	5.55	88.2	35.2	143	0.17	0.88	602	7.5	11.4	16	0.97	1.96
11	6.1933	1896.75	5.50	22.9	161.8	349	5.72	85.6	34.8	147	0.19	0.88	576	7.2	11.1	14	0.97	1.96
13	7.5366	1876.16	5.13	22.0	171.8	293	6.34	74.8	31.1	137	0.09	0.83	556	6.4	11.4	11	0.79	1.99
15.5	9.2436	1849.99	5.41	22.1	162.2	334	5.81	80.4	32.0	137	0.09	0.81	616	6.5	9.3	14	0.78	2.08
18.5	11.2682	1818.96	5.43	23.0	166.5	339	5.95	79.9	31.5	139	0.12	0.92	574	9.0	9.9	9	0.88	2.01
21.5			5.32	21.2	156.8	336	5.82	77.6	31.4	135	0.14	0.89	558	7.0	12.1	11	0.96	2.09

Table 14. NOAA-IV (33°41.67'N, 118°22.78'W; water depth = 457 m)

Mid-depth (cm)	Cumulative mass (g/cm ²)	Time of deposition (A.D.)	Al %	Si %	Cr ppm	Mn ppm	Fe %	Ni ppm	Cu ppm	Zn ppm	Ag ppm	Cd ppm	Ba ppm	Pb ppm	As ppm	Se ppm	Sn ppm	Sb ppm	Hg ppm
0.25	0.0690	1991.26	6.95	25.8	163	465	4.07	70	85	175	2.80	3.25	770	38.9	13.8	24	17.0	1.86	0.14
0.75	0.2475	1990.18	7.06	24.4	183	464	4.17	77	97	186	3.14	4.09	777	42.7	9.4	21	19.0	1.93	0.18
1.25	0.4733	1988.80	6.86	24.2	181	466	4.07	73	95	186	2.95	4.19	758	41.8	8.5	21	19.3	2.07	0.18
1.75	0.7092	1987.37	6.86	24.6	170	467	3.93	68	88	174	2.88	3.66	756	40.0	9.7	22	19.6	2.06	0.16
2.25	0.9514	1985.90	6.86	25.3	170	470	3.96	70	90	177	2.96	3.66	769	39.7	9.4	19	17.3	1.81	0.16
2.75	1.1987	1984.39	6.98	23.7	177	473	4.00	72	95	190	3.23	4.46	762	42.3	10.3	21	18.3	1.97	0.20
3.5	1.5978	1981.97	6.79	22.7	189	457	3.85	68	91	205	3.26	5.55	748	43.6	8.8	21	18.3	2.06	0.25
4.5	2.1770	1978.45	7.00	25.2	200	476	3.99	75	109	238	3.21	7.48	786	49.3	11.0	21	22.5	2.54	0.34
5.5	2.8106	1974.60	7.17	26.3	215	481	3.98	76	112	241	3.53	7.98	802	51.8	12.9	20	22.5	2.55	0.36
6.5	3.4870	1970.49	6.97	26.1	210	478	3.93	70	105	256	3.69	9.18	808	55.0	10.4	21	21.8	2.49	0.42
7.5	4.2081	1960.48	7.20	25.8	150	498	3.85	63	77	205	2.28	5.70	811	40.6	9.5	22	13.1	2.4	0.26
8.5	4.9654	1949.97	7.29	25.5	124	502	3.82	59	63	169	1.82	4.08	767	32.8	8.6	22	10.8	1.93	0.18
9.5	5.7468	1939.13	7.26	26.6	115	501	3.83	57	59	167	1.59	3.83	786	30.2	8.4	23	9.42	1.79	0.17
10.5	6.5496	1927.99	7.16	27.1	92	512	3.83	56	42	142	0.94	2.17	775	22.4	7.0	22	6.28	1.97	0.09
11.5	7.3660	1916.67	7.25	25.6	107	512	3.89	56	51	150	1.14	2.69	815	24.4	7.0	20	7.37	1.86	0.11
13	8.6460	1898.91	7.11	25.7	78	517	3.77	53	35	119	0.56	1.54	785	16.2	7.9	20	4.19	1.54	0.06
15	10.4101	1874.43	7.30	25.6	75	527	3.80	49	34	117	0.39	1.30	812	14.5	5.6	17	3.56	1.41	0.05

Table 15. NOAA-V (33°34.87'N, 118°25.58'W; water depth = 887 m)

Mid-depth (cm)	Cumulative mass (g/cm ²)	Time of deposition (A.D.)	Al %	Si %	Cr ppm	Mn ppm	Fe %	Ni ppm	Cu ppm	Zn ppm	Ag ppm	Cd ppm	Ba ppm	Pb ppm	As ppm	Se ppm	Sn ppm	Sb ppm
0.25	0.0275	1990.88	5.22	18.5	137	331	6.69	115	44.2	136	0.98	1.91	835	20.2	56.5	50	4.60	3.27
0.75	0.1064	1988.59	5.81	16.8	139	354	4.99	108	48.4	137	1.09	1.87	888	26.0	13.0	43	5.32	2.78
1.25	0.2212	1985.25	6.05	20.5	145	373	4.45	111	54.1	146	1.18	1.57	813	38.6	7.1	59	7.80	2.89
1.75	0.3526	1981.43	6.30	20.9	168	367	4.28	95	62.7	154	1.53	2.33	864	36.3	6.7	50	10.4	3.38
2.25	0.4880	1977.49	6.24	20.8	199	368	4.12	93	71.9	167	1.98	2.76	1064	39.6	5.7	45	13.3	3.24
2.75	0.6238	1973.54	6.25	21.1	196	382	3.94	94	66.2	172	1.77	3.38	4214	42.1	5.3	49	13.2	3.04
3.25	0.7588	1969.62	6.11	19.7	185	364	3.94	90	62.0	169	2.11	3.46	5368	57.7	4.4	49	7.86	3.33
3.75	0.8947	1965.66	6.01	18.7	159	367	4.15	90	56.9	167	1.82	2.97	1379	32.0	5.1	45	5.06	3.07
4.5	1.0977	1959.76	6.06	20.2	131	369	3.77	92	57.6	147	1.27	2.13	922	35.2	6.9	46	4.43	4.63
5.5	1.3852	1942.10	6.51	21.6	106	405	4.26	83	41.8	136	0.60	0.69	832	19.1	5.2	53	4.24	3.08
6.5	1.6988	1922.83	6.85	22.8	99	425	4.40	89	38.7	144	0.38	0.74	857	13.9	4.0	62	1.65	1.76
7.5	2.0343	1902.23	6.99	22.1	99	438	4.33	93	38.8	136	0.35	0.81	876	11.3	7.3	68	1.08	1.97
8.5	2.3953	1880.05	6.81	22.6	102	427	4.28	92	39.5	145	0.34	0.96	903	10.5	5.6	61	1.53	2.85
9.5	2.7775	1856.58	6.84	22.5	104	425	4.50	94	40.4	139	0.32	1.04	899	10.1	5.5	65	1.60	2.26
11	3.3760	1819.81	6.69	23.5	104	412	3.98	95	38.9	114	0.30	0.95	944	9.9	3.7	51	1.98	2.16
13	4.1907	1769.76	6.53	23.7	104	409	3.81	95	38.1	139	0.30	0.96	953	9.2	4.2	48	1.75	1.69

Table 16. NOAA-VI (33°29.80'N, 118°19.92'W; water depth = 889 m)

Mid-depth (cm)	Cumulative mass (g/cm ²)	Time of deposition (A.D.)	Al %	Si %	Cr ppm	Mn ppm	Fe %	Ni ppm	Cu ppm	Zn ppm	Ag ppm	Cd ppm	Ba ppm	Pb ppm	As ppm	Se ppm
0.25	0.0437	1987.13	6.13	19.8	130	377	5.18	85	48	147	0.93	0.90	873	21.0	26.1	19
0.75	0.1488	1983.60	6.00	19.6	124	364	5.18	80	47	136	0.85	0.84	828	24.4	29.5	14
1.25	0.3087	1980.00	6.05	20.3	130	382	4.37	90	40	165	0.71	0.79	755	18.9	13.8	15
1.75	0.4860	1977.70	6.34	21.1	139	380	3.97	93	49	141	1.01	1.07	799	25.3	3.3	13
2.25	0.6349	1975.43	6.27	19.8	157	362	3.77	87	62	153	1.57	1.66	1208	34.2	5.5	18
2.75	0.7750	1960.79	6.07	19.9	146	362	3.69	88	54	151	1.43	1.83	1124	30.4	4.6	16
3.25	0.9177	1945.89	6.45	18.8	122	389	3.95	86	53	140	0.82	0.98	827	23.8	6.5	17
3.75	1.0683	1930.17	6.68	21.2	107	411	4.37	85	47	134	0.44	0.46	881	17.8	4.9	18
4.5	1.3059	1905.36	6.81	20.1	98	411	4.53	88	45	124	0.28	0.57	855	13.4	2.2	20
5.5	1.6341	1888.57	7.10	22.7	100	428	4.57	90	46	120	0.24	0.72	920	12.4	4.8	23
6.5	1.9786	1870.95	7.07	22.9	100	418	4.41	87	46	115	0.27	0.84	937	11.7	2.5	21
7.5	2.3377	1852.58	7.09	23.2	96	421	4.23	93	44	115	0.25	0.88	935	11.0	2.1	19
8.5	2.7123	1833.42	6.98	20.9	66	413	4.08	89	44	136	0.20	0.96	963	10.8	1.0	21
9.5	3.1531	1810.87	6.77	22.3	96	403	3.89	89	43	117	0.23	0.86	905	10.5	2.5	18
11			6.52	22.2	97	400	3.94	82	42	117	0.22	0.77	956	10.0	3.6	18
13			6.66	21.7	101	406	3.85	83	43	116	0.25	0.96	994	9.5	4.3	21

Table 17. CaBS XI-1 (33°45.54'N, 118°50.88'W; water depth = 904 m)

Mid-depth (cm)	Cumulative mass (g/cm ²)	Time of deposition (A.D.)	Al %	Si %	Cr ppm	Mn ppm	Fe %	Ni ppm	Cu ppm	Zn ppm	Ag ppm	Cd ppm	Ba ppm	Pb ppm
0.125	0.0123	1989.32	4.61		102		8.43	67	40	120	2.26	3.41		25
0.375	0.0373	1987.79	4.31		129		8.73	59	42	127	2.14	2.54		24
0.625	0.0627	1986.24	4.28		103		7.75	57	39	114	1.76	2.07		20
0.875	0.0909	1984.51	4.88		87		6.66	70	41	120	1.71	2.20		22
1.125	0.1227	1982.56	5.13		95		5.49	72	53	126	1.06	2.36		23
1.375	0.1575	1980.43	5.24		124		4.62	66	49	128	1.61	2.12		26
1.625	0.1973	1978.00	5.80		134		4.23	70	51	135	1.71	2.24		25
1.875	0.2441	1975.13	6.00		117		4.14	69	54	142	1.67	2.31		30
2.25	0.3252	1970.16	6.05		152		3.96	81	55	144	2.33	3.03		38
2.75	0.4360	1963.38	6.01		176		4.03	77	59	153	3.07	3.53		38
3.25	0.5487	1956.47	6.03		182		4.17	74	56	151	3.01	4.53		37
3.75	0.6683	1949.15	5.64		163		4.02	78	52	147	2.79	3.95		34
4.25	0.8046	1940.81	6.50		126		4.21	83	41	130	1.06	2.09		28
4.75	0.9586	1931.37	5.81		117		4.61	76	41	127	0.76	1.62		21
5.5	1.1920	1917.08	6.58		99		4.70	75	39	131	0.59	1.15		19
6.5	1.5135	1897.40	6.34		102		4.30	73	37	114	0.43	1.38		13
7.5	1.8587	1876.26	6.42		97		4.55	70	35	104	0.36	1.54		7
8.5	2.2078	1854.88	6.29		97		4.75	70	35	105	0.40	1.20		7
9.5	2.5373	1840.25	6.28		98		4.83	78	36	104	0.47	1.08		7
11.5	3.0302	1818.36	5.82		102		4.02	78	33	93	0.52	1.72		6
13.5	3.6979	1788.71	5.72		98		3.92	76	32	92	0.55	1.67		7
15.5	4.3601	1759.31	6.00		100		4.10	75	34	94	0.50	1.45		8

Table 18. CaBS XI-4 (33°41.78'N, 118°30.78'W; water depth = 780 m)

Mid-depth (cm)	Cumulative mass (g/cm ²)	Time of deposition (A.D.)	Al %	Si %	Cr ppm	Mn ppm	Fe %	Ni ppm	Cu ppm	Zn ppm	Ag ppm	Cd ppm	Ba ppm	Pb ppm
0.25	0.0289	1988.70	5.98		79		4.99	49	56	97	1.30	1.16		30
0.75	0.0988	1985.35	6.11		92		4.30	49	55	96	1.42	0.89		16
1.25	0.1905	1980.97	5.71		151		3.73	46	61	94	1.51	1.20		30
1.75	0.2994	1975.76	7.22		118		4.69	59	75	138	2.1	1.24		49
2.25	0.4218	1969.90	6.84		178		4.40	58	68	122	2.28	1.28		22
2.75	0.5546	1963.56	6.86		178		4.47	57	65	125	2.23	1.20		25
3.25	0.6974	1956.73	7.00		94		4.48	60	62	122	2.15	1.06		36
3.75	0.8488	1949.49	7.01		120		4.60	62	66	126	2.10	1.18		25
4.375	1.0524	1939.75	6.84		112		4.52	61	58	117	1.85	1.24		23
4.875	1.2252	1931.49	6.71		119		4.49	60	50	112	1.38	0.77		28
5.5	1.4738	1919.60	7.05		125		4.62	58	46	107	1.07	1.14		17
6.5	1.8847	1899.95	7.11		80		4.53	58	40	107	0.77	1.05		19
7.5	2.2996	1880.11	6.58		61		3.95	50	37	91	0.61	0.63		21
8.5	2.7753	1857.36	8.10		89		4.87	57	45	107	0.43	0.58		21
9.5	3.1481	1839.54												
10.5	3.5901	1818.40												
11.5	4.0460	1796.60	6.98		48		4.28	50	38	92	0.28	0.51		15

Table 19 . Inventory ($\mu\text{g}/\text{cm}^2$) of anthropogenic metals in sediment cores from the Santa Monica-San Pedro Basin.

Core No.	Ag	Cd	Sn	Cu	Zn	Cr	Sb	Pb	Ba
NOAA-I	5.3	1.6	20	89	130	200	0.6	60	220
NOAA-II	0.9	1.3	3.3	16	44	52	1.5	14	140
NOAA-III	0.4	0.4	2.2	8.5	52	56	n.d.	12	n.d.
NOAA-IV	15	26	76	330	550	580	5.0	170	n.d.
NOAA-V	1.5	2.2	8.3	31	41	92		36	1290
NOAA-VI	0.8	0.8	2.7	10	44	48	2.0	16	140
CaBS XI-1	1.6	1.6		16	49	49		26	190
CaBS XI-4	1.8	0.8		31	31	82		15	

Table 20. Inventories (ug/cm²) of excess metals in cores collected at key locations in different times

Location	Time collected	Cr	Zn	Ba	Pb	Sb
Eastern slope of Santa Monica Basin						
NOAA-I	Sept., 1991	200		220	60	0.6
CaBS I-40	Oct., 1985	193			50	0.5
Central Santa Monica Basin						
CaBS XI-1	Jan., 1990	49	49	190	26	
CaBS III-1	May, 1986	36	23	193	16	
CaBS III-31	May, 1986	44	32	220		
Southern San Pedro Basin						
NOAA-VI	Sept., 1991	48	44	140	16	
CaBS V-9	Apr., 1987	40	28	169	19	



**Part II: Historical Trends in the Deposition of Organic Pollutants in the
Southern California Bight**

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EXECUTIVE SUMMARY

In 1991, a study was initiated to construct the historic profiles of organic contaminants such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and chlorinated pesticides in the sediments of Santa Monica and San Pedro basins, off the California coast. Surface intact box core sediments were collected from six sites both for trace organic and trace metals contaminants. The cores were subsectioned to yield ~2-4 yrs interval in the recent years and the organic analyses was conducted with sections dating back to 1900 while sections down to 1800 yr from the glass subcores were sent to Oregon State University for Pb-210 and trace metals analyses. The samples were also analyzed for total organic carbon and nitrogen.

The total polycyclic aromatic hydrocarbons (PAHs) range in concentration from 20 to 5000 ng/g. Their content increases steadily and rapidly from early 1900s and reaches a maximum between 1960-1980. This coincides with the onset and the increase of industrial activities. The general trend of subsurface maximum also reflects the wastewater inputs into the bight and subsequent improvement in the wastewater treatment technology. Some offshore cores have organic carbon and contaminants derived from dumpsites.

Concentrations of total PCBs between 50 to 250 ng/g are common in the study sites. The core profiles exhibit an increase and a subsequent decrease of PCB content in recent times. However, decline in PCB content in surface sediments has been slow and not proportionate to the recent decreased inputs from the outfalls (i.e. JWPCP). The historic trends in the distribution of the more highly chlorinated species (PCBs with 4-7 chlorine atoms) is very similar to that of total PCBs since commercial PCBs contained the former congeners as their major constituents.

The total chlorinated pesticides range in concentration from 1 to 13800 ng/g, of which DDTs constitute ~98% in most of the upper sections. Sediments of early 1900s contain 70-80% of DDTs. The non-DDT pesticides range in their content from the limit of their quantitation to ~40 ng/g, most of them ~1 ng/g. Currently, agricultural runoff and airborne transport from land are the major conduits of inputs to the ocean sediments. The content of chlorinated pesticides progressively increases to a maximum around 1965-70 and decreases steadily in recent times.

In summary, the distribution of PCBs and DDTs in some cores mimic the wastewater input and subsequent source control in the region. Specific sections in a few cores also represent significant to major inputs from dumpsites in the region, consistent with high Ba levels reported by others. The anomalously high concentration of DDTs (especially DDT isomers) derived from dumpsites is further documented by the specific ratios of 2,4'-DDT to 4,4'-DDT characteristic of caustic or acid wastes from DDT manufacture. The elevated PAH contents in the same horizons suggests that the DDT wastes were dumped along with petroleum refinery wastes. From the available data, a rough estimate of dumpsite inputs into these sediment horizons could be made.

INTRODUCTION

Coastal sediments in southern California receive contributions of organic pollutants from a variety of sources such as sewage outfalls, storm runoff, dredge disposal, industrial wastes, etc. Historic profiles of selected contaminants in the region have been documented using dated sediment cores because sediments integrate and retain records of toxic pollutants influx. Such historical studies have resulted in stringent laws as well as improved technologies in curtailing waste disposal into the ocean waters in particular, from pesticides manufacturers since the late 1970's. Heavy contamination of sediments with DDT in the southern California coast in the 1950-1970's was determined to be from the discharge of wastes from the Montrose Chemical Company, the world's largest manufacturer of DDTs at that time via Los Angeles County sewer system (Redner and Payne, 1971). About 250-300 kg/day of DDT was estimated to be discharged through the facility (Carry and Redner, 1970; MacGregor, 1976). Beginning early 1971, the wastes of DDT manufacture were diverted to a landfill and the amount entering the ocean dropped drastically, concomitant with improved sewage treatment and source control measures (SCCWRP Reports, 1972-1989; Stull et al., 1986).

Study on historical trends in the distribution of polycyclic aromatic hydrocarbons (PAHs) in the southern California Bight has been very intermittent at best (Reed et al., 1977; Venkatesan et al., 1980; Shaltiel et al., 1979; Amit et al., 1980; Shokes and Mankiewicz, 1979). A systematic data base is certainly lacking in this area. The past studies from sediment cores from San Pedro and San Nicolas Basins (Venkatesan et al., 1980; Shokes and Mankiewicz, 1979) suggest that PAHs from both petroleum as well as combustion of fossil fuels are present in the region and that more recent sediments dominate in pyrolytic PAHs than deeper horizons, although input of these compounds from sewage outfalls cannot be overlooked. Studies by Simoneit and Kaplan (1980) further substantiate the long range transport of terrigenous biogenic PAHs, i.e. retene and pyrolytic PAHs via currents and/or by atmosphere. Anderson and Gossett (1987) found highest concentrations of total PAHs ($15 \mu\text{g g}^{-1}$) in the vicinity of sewage outfalls, harbors, and at the mouths of urban drainage channels.

A number of surveys of chlorinated hydrocarbons have been conducted in the region (Hom et al., 1974; MacGregor, 1974, 1976; Young et al., 1977; Brown et al., 1986; Stull et al., 1988). Decrease in DDT contents of mussels collected in 1974 relative to 1971 established the Los Angeles County outfalls as the point source (Young et al., 1976; Risebrough et al., 1967).

PCBs were synthesized from ca. 1929 to 1977 as commercial mixtures (Aroclor) primarily for industrial use as insulating fluid in transformers and condensers mainly by Monsanto Chemical Company. PCB contamination caused severe poisoning incidents in the late 1960's, which led to the ultimate ban on their manufacture and usage in the 1970's (Cairns and Siegmund, 1981; Alford-Stevens, 1986 and references therein). The earliest measurements of PCBs in Southern California from various sources were made only in 1973 by Young et al. (1975) in spite of the historical use of these compounds from the late 1920's. Subsequent studies documented the PCB contamination in sediments accumulating near submarine sewer dischargers (Young et al., 1975; Young and Heesen, 1978; Word and Mearns, 1979). A survey of surface sediments by Word and Mearns (1979) pointed towards a concentration of contaminants in the vicinity of Los Angeles and San Diego with total PCBs as high as $10.9 \mu\text{g g}^{-1}$ in San Pedro Shelf. The persistence of these hot spots was later confirmed by Thompson et al. (1987). The measurements of Young et al. (1975) showed that in 1971 the top 2 cm contained the highest PCB content but the amount declined dramatically downcore. Recently, Stull et al. (1986, 1988) demonstrated that the JWPCP emissions of PCBs and their steady recent decline paralleled vertical PCB content profiles in shelf sediments collected in the vicinity.

The limited studies on the organic contaminants along with extensive data on trace metals show that the pollutants level peaked in the 1960-1970s (Mearns et al., 1991; Valette-Silver, 1992). Further, most of the analytical studies discussed above were performed in the 1970's and early 1980's. Except for isolated reports by NOAA (NOAA Technical Memorandum, 1988), new data on these components from recently cored sediments, especially from deeper waters, documenting the effects of improved technologies or any detailed studies to differentiate their source inputs are lacking. This investigation was undertaken to measure the abundance and to

understand the depositional history and fate of these chemicals (PAHs, chlorinated pesticides and PCBs) in fine resolution sediment sections each representing a period of 3-5 yrs and dating back to ~1900 from selected locations of the Santa Monica and San Pedro basins. Complimentary organic geochemical data for some of these samples are also available from our earlier studies performed under California Basins Study (CaBS) program.

ANALYTICAL METHODS

1. Introduction

Many toxic components such as polycyclic aromatic hydrocarbons (PAHs) and chlorinated hydrocarbons [pesticides and polychlorinated biphenyls (PCBs)] have to be measured at trace levels from parts per billion to parts per trillion to provide a meaningful basis for environmental assessment. Apparently, extreme care and caution are required while making these measurements to gather reliable and reproducible data.

Sediment core samples were processed following methods optimized at UCLA to analyze aromatic and chlorinated hydrocarbons from the Santa Monica and San Pedro basins from the southern California borderland.

2. Sample Collection and Preservation

Sediment cores were collected by UCLA team in September 1991 onboard R/V Seawatch using slow-entry Soutar Box corer to ensure collection of undisturbed surface horizons from SM/SP basins (Fig. 1). Onboard the ship, supernatant water was carefully siphoned off so as not to disturb the surface layer. Aluminum and glass core liners were used respectively to subsample for organics and trace metals measurements. The cores were sealed with teflon liners and plastic caps and frozen upright immediately onboard the ship and transported frozen to UCLA in dry ice.

The cores were slightly thawed and subsectioned into 0.5 to 2 cm slices and collected onto teflon sheets very carefully using stainless steel wires and thick teflon spatula. The near surface sections were expected to correspond to 2-4 yrs. of time interval (especially after 1970) based on sedimentation rate data known for the general sampling sites in the basin. The sections were stored frozen in organically clean glass jars. All subsections from glass cores were processed similarly and transported frozen to Dr. Huh, Oregon State University for trace metals and Pb-210 measurements. Aliquots of selected subsections from aluminum cores were also dated by Pb-210 to crosscheck for accuracy and homogeneity in the subcores within the box core.

3. % TOC and N Analysis

About a gram of wet sediment was freeze-dried and shipped to Marine Science Institute, UCSB for % TOC and N measurements by their automated CHN analyzer. Samples were pretreated with acid to remove carbonate. A precision of ± 0.5 weight percent or better is achieved with sample sizes greater than 500 microgram. The absolute limits are about ± 2 microgram for carbon and ± 1 microgram for nitrogen. 'Citrus', a NIST reference material, is used as control. Several duplicate samples were also run to check for precision.

4. Removal of Matrix Interferences and Potential Contaminants

Contaminants in reagents, solvents, glassware and other hardware coming in contact with sample during processing may cause interference in instrumental analysis. Some contaminants could even lead to false positives. Only reagent grade reagents were used and necessary precleaning of all reagents were performed. Procedural blanks were run with every batch of analysis (one blank for every 15-20 samples analyzed in a batch) to check for interferences.

Elemental sulfur and asphaltenes were frequently occurring matrix interferences in these samples. Activated copper was used to remove sulfur. Asphaltenes were precipitated with hexane from the concentrated methylene chloride extract of the sediment.

5. Glassware, Reagents and Apparatus

5.1. Glassware

Glassware was cleaned with soap and water, soaked in chromerge for at least one hour, rinsed with tap water, deionized water and Milli-Q+ water and methanol and dried in the oven. They were stored capped with aluminum foil. Just before use, glassware was rinsed once with methanol and twice with methylene chloride.

Two ml vials for storing fractions were bought precleaned with teflon lined septum caps. The vials were sonicated twice with 1:1 mixture of methylene chloride and methanol.

Chromatographic column was 300 mm x 10 mm ID with a funnel fused on the top for solvent

reservoir and a teflon stopcock at the bottom.

5.2. Reagents

Milli-Q+ water contained no analytes above the method detection limit. However, it was always extracted with methylene chloride three times before use.

Hexane, methylene chloride and methanol were Fisher Optima grade. Alumina (activated, neutral, Brockmann I, standard grade, 150 mesh, Aldrich) and silica gel (40-140 mesh, Baker analyzed) were sonicated twice with 1:1 CH₂Cl₂:MeOH and dried in the drying oven. Subsequently, alumina was stored at 120°C and only required amount was deactivated with 1% water and equilibrated at least overnight prior to use. Silica gel was activated at 235°C for 16 hrs and used up within five days after activation. Sodium sulfate and sodium chloride (analytical reagent grade) were also cleaned by sonication as above and dried in the drying oven. Sodium sulfate was further baked at 450°C overnight and stored at 120°C and cooled in dessicator just before use. Glasswool was baked overnight at 400°C. Fine copper granules (Mallinckrodt) were soaked in 6N HCl for about 15 min and the acid decanted off. Excess acid was washed six times each with methanol and then methylene chloride and stored in CH₂Cl₂, stoppered tight and used the same day.

All standards and surrogate spiking solutions were made from analytical reagent grade chemicals purchased from Ultra Scientific or AccuStandards. For details see under "Analyses of Target Compounds."

5.3. Apparatus

A Virtis homogenizer with stainless steel shaft and blade was used to extract sediments with organic solvents.

Finnigan 4000 GC/MS with INCOS data system and a 9600 Varian chromatograph was used for the determination of PAHs.

Varian 3500 GC/ECD, interfaced with a Star Work Station, was used to determine chlorinated

hydrocarbons.

6. Procedure: Wet Extraction

6.1. Dry weight determination

Frozen sediment was thawed, stirred and an aliquot (~1 g) was transferred to a preweighed watch glass and heated overnight at 105°C. Then cooled in a dessicator and weighed. The loss of weight was used to calculate the dry weight equivalent of the wet sediment.

6.2. Sample preparation

A larger aliquot ~20-30 g wet weight was transferred to a preweighed centrifuge jar. The wet sediment was spiked with surrogate mixture, stirred and sonicated for 5 min and let sit for 15 min.

6.3. Extraction and concentration

The sediment was then homogenized with 120 ml methanol, centrifuged and the methanol extract saved in a 500 ml round bottom flask. The extraction was repeated three times with 100 ml methylene chloride which was collected in a 1 L round bottom flask using a 10 ml syringe to filter through glasswool.

The methylene chloride extract was transferred to a 1 L separatory funnel and extracted with 100 ml saturated NaCl solution and 100 ml Milli-Q water. The CH₂Cl₂ layer was collected in the same round bottom flask. Methanol layer was extracted into hexane after partitioning from the same saturated NaCl used with CH₂Cl₂ phase. The hexane phase was added to the CH₂Cl₂ extract. This total lipid extract was rotoevaporated to ~20 ml. About 40 ml of Na₂SO₄ was added and left overnight covered with stopcock.

6.4. Asphaltene removal

The clear solvent layer was transferred to a 200 ml round bottom flask, rotoevaporated to ~5 ml. This was transferred to a 40 ml centrifuge tube, asphaltenes precipitated with 25 ml of hexane,

shaken and left in the freezer for an hour. Asphaltene precipitate was centrifuged and washed with 5 ml of hexane three times. The hexane fraction and the rinsings were reduced to ~2 ml and transferred to 4 ml vial and made up to 4 ml. One to 2 ml aliquot was accurately measured into another 4 ml vial, concentrated to ~400 μ l and treated with 1 g of activated copper. More Cu was added, if necessary, to remove elemental sulfur. Most of the samples had significant amount of sulfur. The samples were left overnight in the freezer.

6.5. Column chromatography

The glass column was rinsed with methanol and methylene chloride. With half the column filled with methylene chloride, it was slurry packed with alumina (3.5 g) first and then with silica gel (7 g). About a gram of Na_2SO_4 was added on the top. The solvent was then exchanged into pentane. The sample in hexane was charged on to the column. Aliphatic fraction (f_1) was eluted with 20 ml of pentane. Aromatic fraction containing all PCBs, chlorinated pesticides and PAHs was eluted with 70 ml of 1:1 pentane: CH_2Cl_2 . The polar fraction was eluted with 35 ml of 1:1 CH_2Cl_2 :MeOH and stored frozen.

6.6. Precautions

To prevent intercontamination of samples, same round bottom flask and syringe were used for a given sample throughout from the beginning to the end. Separate, clearly labelled microsyringes were kept dedicated exclusively for designated surrogate or standard solutions.

It was important not to disturb the silica/alumina chromatographic column while running. Otherwise the column tended to crack, possibly affecting the separation. Occasionally when this happened, the column was repeated.

The deeper sections dating older than 1950, in the cores, where contaminants level was expected to be relatively lower were processed in two batches before the analyses post 1950 sections to obtain good background data. This was done to ensure that the older sediments were absolutely free of any potential contamination from the heavily polluted samples of 1960s and

1970s, although extreme care was exercised even otherwise in handling all the samples to avoid intercontamination throughout the project. The clean laboratory procedure blanks indeed document this careful processing.

6.7. Fraction preparation for instrumental analysis

The aromatic fraction eluted from the column was rotoevaporated to ~2 ml and then blown down to near dryness under nitrogen and made up accurately with hexane to 200-500 μ l, depending on the %TOC and chronology of the core interval, in 2 ml vial with teflon coated septum and ~1/2 g of activated copper was added, shaken to ensure removal of residual sulfur and stored frozen until the time of GC/MS and GC/ECD analyses.

7. Quality Control Measures

Quality control samples were processed along with field samples following identical protocol. Procedure blank was run with every batch of sample set of 15-20. Acceptable blank levels were below 2x MDL. If level of any interfering target compound exceeded this limit, samples in that batch would have to be re-extracted and reprocessed. Matrix spike was run in every batch with target analytes spiked at the level of 10x MDL. Surrogate spikes at the level of 10x MDL were used in every sample. Surrogate and matrix spike recovery acceptance criteria will be described under analyses of specific target compounds.

Sediment reference material (SRM 1941) with certified aromatic and chlorinated hydrocarbons concentrations was analyzed to establish control reference data for the working protocol.

Quantitation of chlorinated hydrocarbons and PAHs obtained for the interlaboratory calibration exercises (August 1992), using the protocol established at UCLA, were reported to NIST. From the interlaboratory comparison statistics, it appeared that UCLA was one of the laboratories to have produced acceptable data conforming with the consensus values.

Replicate analyses of a few samples were performed to check for reproducibility of results.

8. Procedure: Instrumental Analysis

8.1. Quantitation of polycyclic aromatic hydrocarbons (PAHs) by gas chromatography/mass spectrometry (GC/MS)

PAHs were quantitated by GC/MS in the selected ion monitoring (SIM) mode using internal standard mixtures. Target analytes, surrogate spikes and internal standards are listed in Table 1. Matrix recovery spike and external standards solution contained the same components made to order quantitatively from Supelco.

The surrogate solution spiked was adjusted initially such that the solution gave a final concentration of 5 ng/ μ l in the aromatic fraction. A solution of internal standard was prepared by diluting a certified standard solution in a volumetric flask to known volume with methylene chloride. They eluted close to but resolved well from the target analytes. Internal standard was coinjected with the fraction such that in each analysis, the final concentration of the internal standard was 15 ng/ μ l.

Matrix recovery spike solution was diluted to the working concentration level and added to the wet sediment to give a final concentration of ~10x to 20x MDL. For samples of high %TOC content, the matrix spike concentration was appropriately increased.

Routine analyses of PAHs were performed in a splitless mode in the Varian 9600 gas chromatograph interfaced with MS. A 30 m DB-5 fused silica capillary (0.25 mm I.D., 0.25 micron film, J&W Scientific) column was used. An electron energy of 70 eV was used and was tuned according to the manufacturer's specifications to maximize the sensitivity of the instrument. An INCOS 4000 data system allowed continuous acquisition, storage and retrieval of all data during and after the GC/MS analyses.

GC/MS operating conditions are as follows: injector temperature 290°C; transfer line temperature 280°C; initial oven temperature 35°C; initial hold time 6 min; 4°C/min to 280°C; 2°C/min to 310°C. Em voltage 1400v; electron energy 70 eV. Source temperature 240°C; scan speed 2s scan⁻¹ from 50 to 550 amu. The MS was operated on SIM mode using appropriate optimum windows to include the quantitation and confirmation masses for the analytes.

A five-point response factor calibration curve was established which demonstrated the linear range of the detector. Standard concentrations used to construct the calibration curve were: 1, 5, 10, 20 and 50 ng/μl. The identification of compounds detected at concentration above the MDL was double checked by the confirmation ions. If the concentration of the target analyte exceeded the linear range of the calibration standards, the fraction was either concentrated or diluted and reanalyzed.

After every 6-8 samples, a calibration check standard (10 ng/μl) was run to check the response for the PAHs relative to internal standards. Daily response factor for each analyte was compared to the initial calibration curve. Analyses would proceed only if the average daily response factors for the analytes fell within ±10-15% of the calibration curve. If it exceeded ±20% of the calibration curve, a five-point calibration was repeated for that analyte in question prior to sample analysis.

The target compounds were identified quantitatively based on relative retention time (RRT) falling within acceptable window. The characteristic masses of each analyte should maximize in the same or within one scan of each other. The retention time should fall within ±12 s (peak width at half height x 3.5) of the retention time of the authentic standard. The mass spectrometer was tuned to perfluorotributylamine (PFTBA) criteria established by the manufacturer. The relative peak heights of the primary ion and secondary ion masses were examined for confirming the identity of the compound.

The response factors of the internal standard relative to each of the calibration standards was calculated using the formula:

$$RF_x = (A_x \times M_{std}) / (A_{std} \times M_x)$$

where RF_x = response factor; A_x = area of compound; M_{std} = concentration of internal standard; A_{std} = area of internal standard; M_x = concentration of the compound.

The actual concentration of the analyte was calculated using the formula:

$$M_x = (A_x \times M_{std}) / (A_{std} \times RF_x)$$

All analyte concentrations were adjusted to the average recovery of the matrix spike analyses listed in Table 2.

Corrective measures should be taken if the target analytes are found in concentrations three times greater than MDL in procedural blank fractions. This was not found necessary in any of our analyses.

The recovery of the surrogate spikes was monitored in each sample by quantitating with reference to the response of the internal standard. Corrective action should be taken whenever the recovery of the surrogates was less than 30% or greater than 130% as follows.

Calculations were double checked for potential errors. Internal standards and surrogate solutions were rerun separately to find out if there was contamination, degradation, etc. Calibration check sample was rerun to check the performance of the instrument. If these checked out correct, it implied possible potential interference to the surrogate but not to the other target analytes. If sample was diluted such that surrogate could not be measured, surrogate recovery was calculated from the run with the concentrated fraction. If there was a real problem, the sample was reanalyzed.

Matrix spike analyses were done with every batch of sample analysis (Table 2). The acceptable matrix spike recovery criteria were that the average recoveries for all 25 compounds must fall between 50 and 120 percent. Any analysis not meeting this criterion was repeated or appropriately qualified.

Standard reference material was analyzed frequently (with every batch of sample). The average percent values fell within 25% of the mean of our previous analyses and were thus considered reliable analyses.

Method detection limits were determined processing standard compounds at low levels (1 ng/ μ l extract) close to the estimated MDL (Federal Register 1984, vol. 49, no. 209, 198-199). Limit of quantitation was calculated after Clesceri et al. (1989). The data are presented in Table 3. The LOQ is little higher than our normal LOQ and thus represents the worst matrix analyzed here.

The data are reported in units of ng/g and the results are reported to two decimal places. Any quantity between MDL and LOQ should be considered detectable but not reliably quantified because of the complex matrix involved in measurement of these compounds.

Representative mass chromatogram for a standard mixture and a sample run are presented in Figures 2 and 3.

8.2. Quantitation of chlorinated hydrocarbons by gas chromatography with electron capture detector (GC/ECD)

Chlorinated hydrocarbons (pesticides and PCBs) were determined by the high resolution, capillary gas chromatography with electron capture detector using internal standard mixtures. Target analytes, surrogate spikes, internal standard, retention time markers are listed in Table 4. Matrix recovery spike mixture consisted of all the target analytes.

Surrogate solution was adjusted initially to give a final concentration of 100 pg/ μ l in the aromatic fraction. A solution of internal and retention time marker compounds was prepared by diluting a certified standard solution in a volumetric flask to a known volume with hexane. Internal standard was coinjected with the fraction such that in each analysis, the final concentration of the internal standard was 100 pg/ μ l.

Matrix recovery spike solution was diluted to the working concentration and added to the wet sediment to give a final concentration of \sim 10x MDL. For samples of high %TOC content, the matrix spike concentration was appropriately increased.

Routine analysis was performed in a splitless mode in the Varian 3500 GC using two columns (DB-5 and DB-1701; 30 m x 0.25 mm I.D. x 0.25 micron film) connected to injector by one meter deactivated fused silica retention gap and a J&W 0.25 mm glass (Y) splitter. Channel B with DB-5 was the working column and Channel A with DB-1701 was used as a confirmation column. Compound identification was considered positive only if it eluted in both columns within the tolerance limits of relative retention window. Because of the better resolution, some compounds, i.e. BZ 153, 105 and 2,4'-DDT were always quantitated on DB-1701 column. All other compounds were quantitated on DB-5 except when interference was suspected from the shape of the peak. Few other PCBs not on the NS&T target list, i.e. 110, 129, 178, were coinjected with standards to check for possible coelution with target analytes in either of the two columns. A Star

Integrator Work Station was used to retrieve and process the gas chromatographic data.

GC/ECD operating conditions were optimized at UCLA to yield the best possible resolution of all the components in both the columns. The conditions used are as follows: injection temperature 260°C, split open after 0.75 min; detector temperature 330°C; temperature program 10 min at 60°C; 15°C/min to 150°C, hold 0.1 min; 2°C/min to 200°C, hold 10 min; 5°C/min to 280°C, hold 40 min. Hydrogen at 40 cm/sec was used as carrier gas. Nitrogen at 30 ml/min was used as make-up gas.

A four point response factor calibration curve was established which followed a non-linear calibration equation as given below from the macro worksheet. General results formula:

$$y = ax^3 + bx^2 + cx + d$$

Results (IS): x in the above formula is replaced with [AT/B] where R = calculated results of the analyte; A = peak area of the analyte; B = area of internal standard; T = amount of the internal standard; a = third order coefficient; b = second order coefficient; c = first order coefficient; d = intercept. The Multipoint Calibration Macro, a custom Excel macro created by using Excel's macro programming language, is designed to process text files from the Varian Star Work Station. The Excel curve fitting functions are used. A second order fit was used in the calculations.

An average calibration factor from the authentic standard of each target analyte was used to calculate its concentration in the sample. Initial calibration was verified by the measurement of calibration standards after every 6-8 samples. A mid-level standard (25 or 100 pg/μl) was analyzed immediately prior to performing any analyses and after every batch of 6-8 analysis. The response factor criteria for an acceptable calibration check was ±15% on average from the initial calibration and no single analyte exceeded ±20 to ±25%. Sample injection of 1 μl with 1 μl of internal standard was made. If the concentration of the target analyte exceeded the calibration range of the standards, the fraction was diluted and reanalyzed. The concentration of various DDT isomers ranged over several orders of magnitude and differed very much from that of PCBs which were relatively lower in a given sample. This necessitated reruns of the same sample at least at three and occasionally four different serial dilutions to quantitate within the calibration range.

Occasionally the fractions from deeper sections were concentrated and reanalyzed.

Analyses would proceed only if the average concentration for all analytes in the calibration check standard sample was within $\pm 15\%$ of the expected value. If the response factor of any single analyte exceeded $\pm 25\%$ of the expected value, the four point calibration was repeated with the standard mixtures before sample analyses.

Procedural blank should not contain any target analyte greater than two times that of MDL. Any source of contamination had to be investigated and corrected.

Sediment samples, quality check samples and procedural blanks were spiked with DBOFB, and PCB 155 to determine individual sample matrix effects during sample processing. Corrective action would be taken if the recovery exceeded the 70 to 130% range.

Calculations would be checked for possible errors. Internal standard solutions would be checked for contamination or degradation. Instrument performance would be checked with a calibration check sample. If necessary questionable sample would be reanalyzed.

Matrix spike analyses were done with every batch of sample analyses (Table 5). The acceptable matrix spike recovery criteria were that the average recoveries for all ~40 compounds must fall within 60 and 120%. Any analysis not meeting this criterion was repeated.

Standard reference material was analyzed with every batch of sample. The average percent values fell within 25% of the mean of our previous analyses and were thus considered reliable analyses.

Method detection limits were determined processing standard compounds at low levels (10 pg/ μ l extract) close to the estimated MDL (Federal Register, 1984, vol. 49, no. 209, 198-199). Limit of quantitation was calculated after Clesceri et al. (1989). The data are presented in Table 6.

The data are reported in units of ng/g. Any quantity between the MDL and LOQ should be considered detectable but not reliably quantified because of the complex matrix involved in measurement of these components. The results are reported to two decimal places.

Representative gas chromatogram for a standard mixture and a sample run are presented in Figures 4 and 5. The figures demonstrate that the target compounds, internal standards and

surrogates are resolved well from one another and from interfering compounds.

RESULTS AND DISCUSSION

General Characteristics of the Cores

Visual examination on board the ship revealed the recovery of all the box cores with very good to excellent surface conditions. An orange flocculent layer was noticed on the top of the cores which constitutes the precipitate of amorphous oxyhydroxides of iron formed at the sediment-water interface (Finney and Huh, 1989). This attests to the recovery of intact surface layer.

Sedimentation rates were determined from Pb-210 data generally by linear regression (Huh, pers. comm.). Because of sediment mixing at the surface layers, chronology for cores NOAA I and NOAA III from the eastern and western slopes was established based on sedimentation rates from below the surface mixed layer. A turbidite layer found at 1-1.5 cm in core VI most probably corresponds to the winter storm of 1979-80 (Huh et al., 1990). NOAA IV has the highest sedimentation rate of the six cores which is rapid enough to mask the effect of mixing over the historical downcore trend of contaminants. For more details see Huh, 1993.

The results of intercalibration of Pb-210 chronology on selected sections from aluminum cores collected for organic contaminants with those from glass cores are presented in Table 7. The cores appear to have been sectioned generally quite uniformly in the subcores as evidenced from the concordance in time intervals represented by the sections except in three of the four mid-sections from cores I and II. The Pb-210 dates in these mid-sections are apparently offset by 10-15 yrs between the two subcores. The Pb-210 dates of mid-sections in cores II and III could therefore be offset on an average by 5-8 yrs as a correction. Yet, it is unclear currently whether this could also be due to inhomogeneity of subcores within the boxcore. Chronology in the mid-sections of these cores will, therefore, be carefully considered in conjunction with DDTs distribution to draw meaningful conclusion.

Total Organic Carbon and Nitrogen

The %TOC ranges from 1.26 to 6.38 in the samples (Fig. 6). Cores II, V and VI have relatively higher %TOC ($\geq 3.0\%$) and %TON $> 0.3\%$ than cores I, III and IV ($< 3.0\%$ and < 0.3

respectively) as expected from the location of the former three cores in the anoxic or hypoxic waters of the deeper SM/SP basins conducive for the better preservation of organic matter. Note that the %TOC is much higher than in sediments from pristine oxic marine environments such as Alaskan continental shelf (Venkatesan and Kaplan, 1982). The C/N ratio falls uniformly within a narrow range of 8-10.1 (excepting for one section at 14.8) in all the samples, reflecting a mixed contribution from marine autochthonous as well as terrestrial inputs to the sedimentary organic matter (Table 8). It is known that ratios around 6 represent inputs of nitrogen from marine organisms (Müller, 1977), while values around 12-14 reflect organic debris from terrestrial plant origin (Prahl et al., 1980).

Peripheral Studies

Since PCBs are present at lower levels than DDTs in the sediments, we attempted to separate the PCBs from pesticide to increase the sensitivity of the former components. Several methods, i.e. the one by Morselli et al. (1989) reported to yield complete isolation of PCBs from other organo-chlorinated pesticides, the use of the newly developed adsorbent Alumina C, meant to adsorb PCBs preferentially from transformer oil, etc. were investigated. None of these separation procedures afforded a clear-cut separation of PCBs from pesticides. A silica gel-alumina column chromatographic method similar to that previously used by UCLA and GERG was now modified at UCLA by repeatedly separating a standard mixture of NS&T target analytes using various solvent mixtures and adsorbent ratios. This procedure provided a good separation of the PAHs and chlorinated hydrocarbons in the aromatic fraction (f_2) from aliphatic (f_1) and polar (f_3) compounds.

Two slightly different temperature programs were developed, one suitable for each of the two columns (DB-1701 and DB-5) to afford separation of all the target analytes in the GC/ECD analyses. However, for routine analyses of the samples, the temperature program ideal for DB-5 was used and DB-1701 generally served as the confirmation column. Few non-target PCBs were also injected to identify potential coelution with the target analytes. PCBs BZ# 110, 129 and 178

were tested. It was found that (i) BZ 110 and dieldrin, (ii) BZ 178, 138 and 4,4'-DDD and (iii) BZ 129 and 187 coelute in DB-1701. On DB-5 column, (i) BZ 110 and BZ 77 and (ii) BZ 126 and 129 could coelute. BZ 178 elutes very close to the second pair. However, BZ 126 was not detected in either of the column in any of the sediment sample in the current procedure. It is likely that BZ 126 requires a different column cleanup for its detection. Based on the above observations, quantitation of specific PCBs was done in the column with least interference. For example, dieldrin, BZ 138 and 4,4'-DDD were always quantitated from DB-5 because dieldrin coelutes with BZ 110 and 4,4'-DDD coelutes with BZ 138 in DB-1701 column. Although BZ 110 could coelute with BZ 77 on DB-5, we found that generally DB-5 gave lower quantitation numbers than DB-1701, suggesting that other unknown compounds could be coeluting with BZ 77 in DB-1701 as well. This prompted us to use DB-5 value for BZ 77. The possibility of coelution of BZ 110 with BZ 77 cannot, therefore, be ruled out and the value of BZ 77 should be considered as an upper limit in all the samples. BZ 105 and 153 were better resolved in DB-1701 than in DB-5 and their quantitation was always done on the former column.

Degradation of target analytes under GC conditions were checked to investigate potential problems in accurate quantitation. At the injector temperature of 260°C in GC/ECD, we found that 3.2% of endrin and 1.8% of p,p'-DDT decompose. Roughly two times of DDE is formed relatively to DDD from the decomposition of p,p'-DDT. Since the SM/SP basin samples contain significant amount of DDTs and the metabolites and the degradation is <4%, which is well below the extraction and procedure recovery levels, the corrections for degradation were not applied to the quantitation data. Note that the recovery of all target analytes including endrin and DDTs are above 50% with a very few exceptions (Tables 5). The recovery was low, $\leq 30\%$ but consistent for naphthalene and 2-naphthalene. Most of the analytes were recovered within the range 60-85%.

Replicate analyses of a few sediment samples were carried out to check for consistent recovery and reproducibility of the analyses for chlorinated hydrocarbons and PAHs. Results of such representative analyses are presented in Tables 9-10. The data show very good to excellent agreement between the duplicates for $\geq 90\%$ of the target compounds documenting the careful

analytical techniques of processing and subsequent measurement with instruments.

Sources of PAHs and the Historic Trends in Their Distribution

The total PAHs range from 20 to 5000 ng/g in the cores (Tables 11a-f) and are comparable to other urban U.S. coastal areas (NOAA, 1988). The gas chromatograms (the total ion current trace in GC/MS) consist of huge humps of unresolved complex mixture (UCM) which decreases with depth. This large UCM of aromatic hydrocarbons and petroleum naphthenes is generally absent in uncontaminated sediments. These sediments contain larger amounts of complex PAH compounds than the sediments remote from areas of natural petroleum seeps or anthropogenic activities (i.e. La Flamme and Hites, 1978; Neff, 1979; Venkatesan et al., 1980, 1987 a, b). Although a significant number of values in Table 11 have been identified as below LOQ, from our past experience of GC/MS performance, most of these values can be considered as reliable numbers in computing total PAHs. The LOQ quoted here applies to the worst case of matrix. The values identified as below LOQ (but above MDL) have therefore been included in the sum of total PAHs. If the methyl homologs were plotted, San Pedro and Santa Monica sediments would show evidence of significant petroleum PAHs largely derived from petroleum seepage, shipping and erosion of shales. The dominance of parent PAH and their monomethyl homologs suggest that sewage outfall and urban runoff of atmospheric pollution fallout from combustion products in the Los Angeles area. Perylene is present in almost all sections of the cores (even in sediments deposited prior to man's activities) in consistently higher amounts relative to many other PAHs, ranging from 6 to 600 ng/g. Perylene could be derived from natural seeps or formed as a result of rapid deposition of sediments containing plant and soil precursors into shallow oxygen-poor water (Aizenshtat, 1973; Venkatesan, 1988) and from marine precursors (Wakeham et al., 1979; Venkatesan, 1988).

The presence of relatively higher amounts of fluoranthene, pyrene, indenopyrene, benzo(b and k) fluoranthenes in all the sections including preanthropogenic period and especially in core III which has the lowest PAH amounts favor the importance of combustion-derived PAHs in the

region.

Stations IV and V from the San Pedro basin contain much higher PAHs than either station VI which is farther offshore or stations I and II from the Santa Monica basin. Station III in SM/SP basin contain the least PAHs. Of all the stations sampled here, station IV is the closest to the JWPCP outfall and, therefore, contains high anthropogenic inputs of organic contaminants. Station I in the eastern slope nearshore and station II from the central Santa Monica Basin farther offshore contain similar PAH contents. This may be because of better preservation of organic matter in anoxic waters of the central basin and the affinity of organic carbon for fine-grained clayey rather than silty sediments. Station III in the SM/SP exhibits the lowest PAHs content and sections below 7cm dating year 1929 contain the least amounts of PAHs in all the sections investigated.

Historic profiles of the cores are illustrated in Figure 7. The historic record in core I is fuzzy because of bioturbation. In other cores, the PAH concentration appears to increase steadily and rapidly from early 1900s, with the onset of industrialization and reaching a maximum between 1960-80. Similar observations from cores from very close locations, i.e. BC40 close to NOAA I and BC89 close to NOAA II, were made by Venkatesan and Kaplan (1987), where the former core showed a steady decline in PAH content while the latter from central basin exhibited a subsurface maxima between 2-4cm corresponding to 1940-66 (Fig. 8). This is also consistent with the general observation along the U.S. coasts (Valette-Silver, 1992). With the exception of stations III and IV, the other cores show a decline in the PAH content in the surface sediments beginning 1970-1980s. Core III exhibits a steep decline in PAH content prior to 1979-83 and has the lowest level of contamination with no subsurface maximum. However, its surface value is comparable to cores I, II and V. The sediment accumulation rate at this site is very high and the top 5cm is mixed resulting in the loss of historic record after ~1940. Further, this site is not located along the main California Counter Current trajectory which transports anthropogenic contaminants along the coast and offshore of the California borderland. A similar lack of subsurface maxima was also noted by Huh (1993) in this study on anthropogenic metals in this core. Present day PAH levels in the

sediments are generally greater than 11-75 times assuming that pre-1930s sediment sections in station III correspond to background levels of PAH (~35 ng/g) for the study area.

Core IV exhibits a subsurface maximum around 1982-86 unlike other cores. Note that one of the sections, 2-3cm (1984-86) was analyzed in duplicate and gave concordant values (Table 10). We are not aware of any oil spill during this period in the region and the reason for this spike is currently unknown. The data on PCBs and DDTs obviously do not show the maximum at this interval because of their ban on production and/or source control since 1971.

Despite its greater distance from point sources (i.e. outfalls), station V shows an equally abundant PAH levels to that of IV. Anomalously higher amounts of methylated homologs of naphthalene (mono, di and tri) and methylated phenanthrene (higher homologs not yet quantitated), characteristic of petroleum, are noticed in the sections at subbottom depth 3-6cm, corresponding to 1942-70. This trend is particularly striking in the section 4-5cm deposited during 1960 (Table 11e; Fig. 7). This would indicate a source from offshore dumping rather than from JWPCP. Note that station V is much closer to the dumpsite II where wastes from petroleum industry were dumped (Chartrand et al., 1985). In an earlier study, Venkatesan et al. (1980) found that aromatic hydrocarbons input was at its peak from 1966 to 1968 in a nearby location from San Pedro Basin. This trend is consistent with the anomalously high Barium content observed within this time interval in this core by Huh (1993) and in another core about 1km west of this station corresponding to the period 1963-73 by Ng and Patterson (1982) which was attributed to the petroleum wastes (abundant in Barium) dumped in the general region. (See under chlorinated hydrocarbons for more details.)

Sources of Polychlorinated Biphenyls (PCBs) and the Historic Trends in Their Distribution

The total PCBs range in concentration from <1 ng/g to 374 ng/g (Tables 12a-f). This is generally less than the total PCBs reported for San Pedro Bay (450 ng/g) and Santa Monica Bay (720 ng/g) sediments, Palos Verdes Shelf (980 ng/g; NOAA, 1991) and several west coast bay and

harbor sediments but greater than other areas throughout coastal United States (NOAA, 1988). Non- and mono-ortho coplanar PCBs (i.e. BZ77, 105 and 118) constitute between 1 to 38% of the total PCBs in the sections. Specifically, these PCBs are considered to be the most toxic of the PCBs analyzed here. The fourth PCB (non-ortho), BZ126 which is also considered toxic was not detected in any of the samples. It is likely that the current procedure adopted at UCLA does not recover this PCB for accurate quantitation.

PCBs are among the most commonly measured contaminants in sediments of the California borderland (SCCWRP, 1969, 1981; NOAA, 1986). Highest mean values have been reported frequently from San Diego Harbor (2.25 $\mu\text{g/g}$), Palos Verdes shelf (0.676 $\mu\text{g/g}$), and Los Angeles and Long Beach harbors (2.6 $\mu\text{g/g}$). More recently, total PCB levels from <1 $\mu\text{g/g}$ to 11 $\mu\text{g/g}$ dry weight of sediments from Los Angeles Harbor have been reported (Eganhouse et al., 1990). PCBs were manufactured in USA from 1929 to 1977 and were sold under the trade name Aroclor as mixture of specific congeners. Until recently PCBs in the environment have been measured and reported in terms of these commercial Aroclor mixtures. With the advent of capillary columns which give high resolution of complex mixtures, individual congeners have been quantitated since the middle of last decade. Because of their low flammability and high stability, PCBs have been utilized in transformers and capacitors, hydraulic fluids, lubricants, plasticizers, dyes, etc. (U.S. EPA, 1984). PCBs were in large use especially in the early 1970s and a ban on their production was enforced in 1977.

Because of their diverse applications, inputs of PCBs to the marine environment can be varied. Although point sources such as municipal waste dischargers can be significant contributor of PCBs to nearshore environment, non-point sources such as refuse incineration and atmospheric transport, industrial effluents runoff, etc. cannot be overlooked. For example, combustion of plastic wrap made of polyvinylidene chloride could generate, even at as low a temperature as 200°C, some of the toxic PCBs (Yasuhara and Morita, 1988). Atmospheric transport of PCBs has been reported to be quite significant on a global scale (Atlas, 1986). A continuous record of combined annual mass emissions of PCBs from the seven wastewater discharges have been

compiled by SCCWRP from 1971-85 (SCCWRP, 1987) and the spatial distribution of PCBs in the Bight has been reviewed by Mearns et al. (1991) and on a global scale by Erickson (1992).

Core IV adjacent to JWPCP outfalls contain the highest PCBs content and Core V which is also in San Pedro Basin, but further offshore in deeper waters shows the second highest and and Core I the third highest content of PCBs. Concentrations of total PCBs between 50 to 250 ng/g are common in these sites which are potentially toxic concentrations (Dexter and Field, 1989) and could be toxic to marine life. Cores II, III and VI contain uniformly low levels. This general trend is concordant with that observed for pesticides suggesting a common source for PCBs and pesticides (see later for details on pesticides), the major source of being sewage outfalls.

Figure 9 illustrates the core profiles of PCB distribution in the SM/SP basins. The common use of PCBs apparently began to escalate from ~1940s peaking around the 1970s after which a decline in their use is noted, as evident specifically in Cores IV and V. This trend is similar for both total and selected (toxic) PCBs. Previously, Hom et al. (1974) analyzed for PCBs in a dated core from anoxic sediments of Santa Barbara basin in 1970. They observed a steady increase in PCBs content from ~1945 through 1967. No recent core study has been undertaken in this site to document the recent decline in their concentration concomitant with the source control. Surface sediment grabs and short cores have been investigated by Stull et al. (1988) along the Palos Verdes shelf. The core profiles exhibit an increase and a subsequent decrease in the recent times of PCBs content. Although PCB mass emissions from JWPCP outfalls has decreased by more than 99% from ~1300 kg in 1973 to ~80 kg in 1985 and below detection in 1988 (SCCWRP, 1988), the rate of decline of PCBs in surface sediments off Palos Verdes is not proportional to this decreased inputs (Mearns et al., 1991). An analogous trend is clearly evident from Figure 9, especially from cores I, II, IV and V where concentration of PCBs in the surface stratum is not trivial. Apparently, there is a significant increase in PCBs content in the surface section in Core IV corresponding to 1990-91. It is not clear if this elevated surface level can be fully justified by sediment mixing. Eventually the sediment layers containing toxic contaminants should get buried beneath "cleaner" sediments to deeper levels where they are not bioavailable for marine life.

The target PCBs content has been plotted to show their distribution by the number of chlorine atoms in the congeners in Figure 10. PCBs containing from 4 to 7 chlorine atoms are the major constituents since the advent of the use of these components. Their content is much lower in pre-1900 relative to modern times. This is largely due to the use of total PCBs which has been steadily increasing at least up to 1975. A concomitant increase in the presence of 4-7 chlorinated PCBs is also observed in the cores, because almost all commercial PCBs contained 4-6 and some up to 7 chlorinated congeners as major constituents (Erickson, 1992).

Sources of Chlorinated Pesticides and the Historic Trends in Their Distribution

The total pesticides range in concentration from 1 to 13800 ng/g (Table 13a-f). The DDTs constitute 98% or above of the total pesticides in most of the sections except for a few sediments of the early 1900s which contain 70-80% of DDTs in the total. The maximum concentration of individual non-DDT pesticide ranges from the level of their limit of quantitation to 38 ng/g, most of them ≤ 1 ng/g. Alpha-chlordane, cis-chlordane, hexachlorobenzene and trans-nonachlor are the frequently found other pesticides. Other target compounds were very low in abundance, close to quantitation limits or below detection levels. In general, total non-DDT pesticides in the study sites are below 20 ng/g and appear to have been used beginning 1940s and their use peaked around 1948-70 and continue to be detected in surface sediments (Tables 13a-f). Currently, agricultural runoff and airborne transport from land are the major modes of contamination in the marine sediments. In addition, resuspension and mixing processes could result in many of these compounds finding their way to the top sediment surface, as also observed here. Since DDTs are the major chlorinated pesticides present in these cores, a detailed discussion of their geochemistry is presented here.

Total DDTs (DDTs \equiv 2,4'- and 4,4'-DDE, DDD and DDT) range in concentration from 1 to 13764 ng/g. The upper level found in sediment horizon dating ~1960 from Core V is still lower than in the sediments recovered from 60m water depth in 1977 and 1985 from Palos Verdes Shelf, California (Word and Mearns, 1979) and much higher than those found in east coast sediments

(NOAA, 1988). Cores I, IV and VI contain much higher amounts of DDEs (DDT metabolites), especially 4,4'-DDE, and the down core profiles appear to document the history of wastewater input (Figs. 11 and 12). The presence of DDE in traces only at depths below ~1920 and the abrupt increase in the content above 1940s is consistent with the time when DDT came into common use. The concentration progressively increases up to a maximum around 1965-70 and decreases steadily from then on to progressively lower values. The dominant source of DDE contamination is the industrial wastes discharged via Joint Water Pollution Control Plant (JWPCP) at Whites Point and Hyperion Plant. Major source control became effective in 1974 when JWPCP reduced the discharge of DDE from 22 metric tons in 1971 to ~2 metric tons in 1974. However, surface sediments contained as high as 1000 ng/g shortly after the major source control (Young et al., 1976). This could be due to upward diffusion or resuspension of already deposited material in addition to residual contribution from outfalls. Resuspension and upward diffusion is still the major cause for the presence of DDTs in (modern day) surface sediments at the level of 110 to 4700 ng/g in the cores in Santa Monica and San Pedro basins although these contaminants are being buried deeper and deeper by natural sedimentation with passage of time. The presence of measurable DDTs in sediment trap particles are consistent with this observation (Venkatesan et al., 1994). The traces of DDTs found in bottom cores might be due to mixing as a result of some restricted burrowing. Core III from SM/SP basin contains probably background levels or none of DDTs prior to 1900 (Table 13c). Similar observation were made in a core very close to the NOAA VI in our previous studies (Venkatesan et al., 1980). It is interesting to note that the concentration of DDTs in section 2-3cm of Core IV in San Pedro Basin (5934 ng/g) corresponding to 1984-86 is comparable to that reported for Palos Verdes surface sediments collected from 1984-87 which contained DDTs at the level of 6891 ng/g and much higher than San Pedro Bay sediments (534 ng/g; NOAA, 1988).

Highest amounts of DDTs were detected in mid-sections of Core V in which 2,4'- and 4,4'-DDTs were major constituents in contrast to the three cores discussed above. The DDT content peaked sharply around 1960 in this core (Fig. 12) and reached background levels quickly before

1920s. An interesting observation to be pointed out here is that Core IV which is closer to the JWPCP outfalls than Core V, exhibited maximum concentration of both PCBs (Fig. 9) and DDTs (mainly DDEs; Figs. 11 and 12), around the time interval 1970-75. Numerous prior studies (too numerous to be listed here) have demonstrated that PCBs and DDEs mainly originate from sewer dischargers which is corroborated here by the historic trend in Core IV. In contrast, Core V which contain about half as much PCBs at similar time horizon (1974-77) contain as much DDT (2,4'- and 4,4'-DDT, ~8150 ng/g) instead of DDE which is dominant in Core IV at same level (~8500 ng/g). Apparently, the excess DDTs (2,4'- and 4,4'-DDT) in Core V was not derived from sewage outfalls and requires another major source in this time frame.

It can reasonably be assumed that PCBs and DDTs were present in nearly constant proportion in sewage discharges which were the major sources of these compounds to marine sediments during 1960s-70s, especially in Core IV. Considering the close similarity of the historic profiles of PCBs and DDTs from Core IV nearer to the sewage discharges and the lower PCBs relative to DDTs content in Core V, the amount of DDTs to be expected exclusively from sewage outfalls in Core V can be calculated as follows. Knowing the PCBs content in both cores, and DDTs content in Core IV (since PCBs and DDTs apparently derive from sewage outfalls in Core IV), DDTs content in Core V to be exclusively contributed from sewage outfalls can be extrapolated thus:

$$\frac{\text{DDT in IV}}{\text{PCB in IV}} \times \text{PCB in V} = \text{DDT in V}$$

$$\frac{6277}{324} * 123 = 2382 \text{ ng/g}$$

Thus only about 2400 ng/g of DDTs should have been present in Core V during 1960s-70s if sewage outfalls were the only source. Instead, the actual DDTs contents in 1960 and 1970 are 13764 and 9831 ng/g respectively, about 4 to 6 folds in excess of the expected value in Core V. The excess amount of DDTs must have originated from offshore dumping. This is not surprising from the proximity of station V to Dumpsite II (Fig. 1). These findings confirm our observation

on PAHs from the same horizon as discussed earlier. The data also corroborate the elevated Ba levels at this core section reported by Huh (1993) and the anomalously high barium levels during the same time period (1963-1973) by Ng and Patterson (1982) in another core collected about a km west of this site. The data collectively provide strong evidence for the origin of organic carbon in this section and the adjoining strata from the petroleum wastes of the refineries as well as wastes from DDT manufacture dumped together in the past (Chartrand et al., 1985). Similarly, at 3-4cm subbottom depth corresponding to 1965 in station III, which is in the vicinity of Dumpsite I, equal amount (~80-100 ng/g) of DDTs probably originated from the dumpsite in addition to the sewage-derived contaminants.

Based on our data from different sections of Core V, where dumpsite input is clearly evident, three criteria considered together appear to be essential to assign contamination from dumpsites into the sedimentary stratum in question. (1) Relatively high amounts of DDTs, i.e. at least 25 ng/g of 2,4'-DDT should be present to draw reliable conclusion from the data. (2) Much higher DDTs relative to DDEs should be present, i.e. ratio of DDE/DDT be less than 1. (3) Ratio of 2,4'-DDT/4,4'-DDT should be ≥ 0.18 to reflect their origin either from caustic waste or acidic waste of DDT manufacture (Fig. 13). Applying these criteria suggest that the following sections from the cores could contain organic inputs from chemical waste dumping:

II: 2-2.5cm (1966); 2.5-3cm (1959)

III: 3-4cm (1965); 4-5cm (1956); 5-6cm (1948)

IV: 3-3.5cm (1970); 4-5cm (1960); 5-6cm (1942)

V: 5-6cm (1942)

After correction by 5-8 yrs on an average, the above sections would correspond to the time period II 1960-66, 1954-59; III 1961-65, 1951-56, 1940-48. The general time frame for contamination from dumping remains unaltered and is consistent with that observed in Core V. Barging of caustic wastes from DDT manufacture was effective from 1947 to 1951 while acid wastes were barged from 1951 to 1961 to Dumpsite I (Chartrand et al., 1985). The section in Core III corresponding to 1940-48 exhibits the lowest value (0.28) while the other sections from Cores II

and III exhibit values between 0.32 and 0.56 for 2,4'-DDT/4,4'-DDT (Table 14). The lowest value is within the range reported for caustic waste and technical DDT entering sewage wastewaters (Redner and Payne, 1971; Anderson et al., 1982). Core III closer to Dumpsite I apparently received caustic waste input in late 1940 to early 1950. In contrast, the sediment horizons of 1956-66 in Cores II and III with relatively higher values reflect inputs from acid wastes containing higher proportions of 2,4'-DDT. (Note that even after time offset from PB-210 chronology, same conclusions are valid.) Similar observations for the presence of acid wastes in some Santa Monica Basin cores from shallower waters (BC12, Fig. 1) was reported by Venkatesan et al. (1994) and in other locations in the borderland by Risebrough et al. (1991, pers. comm.). In an analogous manner, sediments during 1960-70s in Core V represent inputs from caustic wastes and probably technical grade DDT, while the significance of the relatively higher ratio in the section dating 1942 is currently not understood. Apparently, the sediments with ratios lower than ~0.18 reflect inputs from outfalls.

Although Dumpsite I was the designated site by the then government body, records from Los Angeles' Regional Water Quality Board (LARWQCB) indicate that California Salvage Company (CSC) had been discharging wastes at 33°34'N; 118°27'W (labelled as DII in Fig. 1), farther east of the San Pedro Basin and north of Santa Catalina Island. The company was later cited for discharging wastes closer to shore. It is possible that a wider area between Los Angeles and Santa Catalina Island was used to "short dump" the wastes (Chartrand et al., 1985). The spread of contaminants from dumpsites to the study sites is possibly from deterioration of the containers with chemical waste and subsequent physical transport and mixing by wave action. Further, Dumpsite I is on the western slope which serves as a narrow connection between Santa Monica and San Pedro basins (Emery, 1960) and the dumped wastes could enter either of the two basins by physical processes. It is not therefore surprising to identify the signature of dumped organics in the two basins interchangeably. However, the available data from this study can not distinguish between material derived from DI or DII. A unique signature specific to material dumped exclusively in each Dumpsite would help resolve this question. Such a criterion may not even be necessary to

understand the geochemistry of the region, as long as the data demonstrate if the organic input has originated from a dumpsite or not. Unfortunately, we do not have a sampling location close to our earlier CaBS site BC12 whose DDT composition suggested possible "short dumping" of chemical wastes (Venkatesan et al., 1994), to document this practice on a fine time line scale.

CONCLUSION

Santa Monica/San Pedro basins are complex environments. The sources of organic inputs have apparently varied over time. Further, these materials have been distributed throughout the basins by sediment transport via the dynamic current systems of the California borderland. This report presents strong evidence that sediments in shallower as well as deeper waters document the history of wastewater inputs before and after the introduction of advanced treatment technology and source control as illustrated by the core profiles of PAHs, PCBs and DDTs distribution. In addition, specific horizons from selected sites reflect inputs from dumpsites I and II. The characteristic distribution of 2,4'- and 4,4'-DDT isomers in these sections helps estimate the amount of organic contaminants from the dumpsites.

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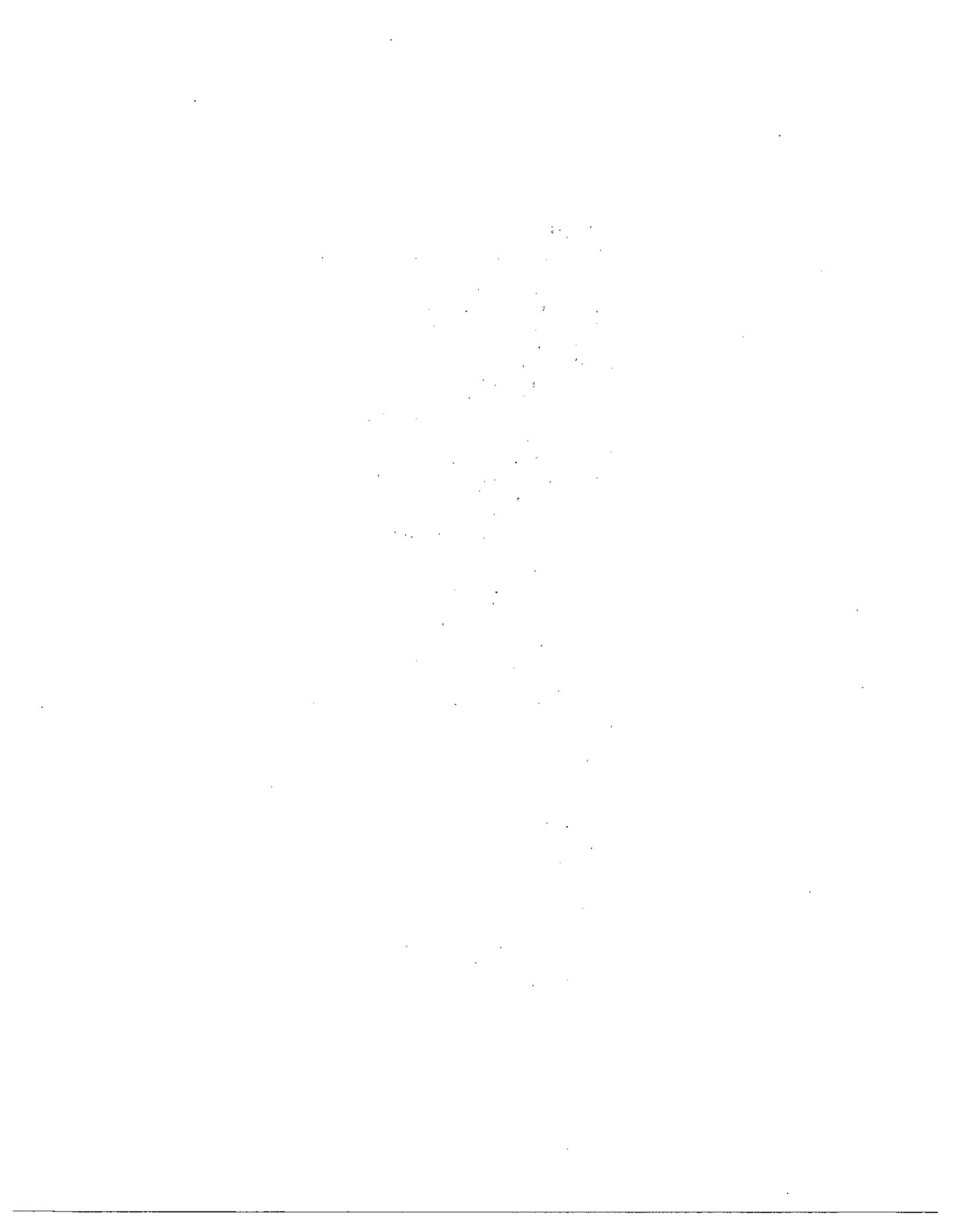


Table 1. PAHs analyzed

Naphthalene (NAP)
2-Methylnaphthalene (2MN)
1-Methylnaphthalene (1MN)
Biphenyl (BIP)
2,6-Dimethylnaphthalene (DMN)
Acenaphthene (ACE)
Acenaphthylene (ACY)
2,3,5-Trimethylnaphthalene (TMN)
Fluorene (FLU)
Dibenz(a,h,)anthracene (DBA)
Indeno(1,2,3-cd)pyrene (INDP)
Phenanthrene (PHN)
Anthracene (ANT)
1-Methylphenanthrene (1MP)
Fluoranthene (FLA)
Pyrene (PYR)
Chrysene/Triphenylene (CHR/T)
Benz(a)anthracene (BAA)
Benzo(b)fluoranthene (BBF)
Benzo(k)fluoranthene (BKF)
Benzo(ghi)perylene (BGHI)
Benzo(e)pyrene (BEP)
Benzo(a)pyrene (BAP)
Perylene (PER)

Internal Standards

Acenaphthene-d₁₀
Phenanthrene-d₁₀
Chrysene-d₁₂
Perylene-d₁₂

Surrogates

Hexamethylbenzene (HMB)
N-Dodecylbenzene (DOD)
4-Terphenyl-d₁₄ (TERP)

Table 2. Matrix spike recovery of PAHs

Compound	Percent Compound Recovered			
	1	2	3	4
Naphthalene	14.90	25.70	15.60	11.10
2-Methylnaphthalene	24.70	30.90	22.80	18.40
1-Methylnaphthalene	27.80	32.30	28.60	20.90
Biphenyl	34.30	35.70	30.40	27.10
2,6-Dimethylnaphthalene	37.80	39.60	31.20	25.90
Acenaphthene	43.50	42.70	35.90	32.80
Acenaphthylene	39.80	39.50	36.30	33.00
2,3,5-Trimethylnaphthalene	54.40	41.90	51.70	46.90
Fluorene	53.50	49.50	51.40	51.00
Dibenz(a,h)anthracene	64.30	60.30	54.20	67.40
Indeno(1,2,3-cd)pyrene	67.30	64.50	56.40	69.60
Phenanthrene	71.40	64.70	66.20	64.90
Anthracene	66.80	64.30	64.50	70.30
1-Methylphenanthrene	72.90	74.00	71.00	78.20
Flouranthene	71.00	66.30	69.60	83.10
Pyrene	77.00	69.60	73.70	90.70
Chrysene	77.20	74.70	76.80	89.90
Benz(a)anthracene	78.20	79.10	84.00	87.00
Benzo(b)fluoranthene	62.00	63.90	59.30	75.90
Benzo(k)fluoranthene	69.60	66.10	58.00	74.50
Benzo(ghi)perylene	63.00	59.70	54.80	66.60
Benzo(e)pyrene	68.00	64.80	57.50	76.80
Benzo(a)pyrene	63.50	63.40	54.40	72.60
Perylene	60.60	58.50	52.40	67.40

Table 2. Matrix spike recovery of PAHs

Compound	Percent Compound Recovered		Average Recovery (%)
	5	6	
Naphthalene	26.30	23.60	19.53
2-Methylnaphthalene	38.30	30.80	27.65
1-Methylnaphthalene	45.10	33.30	31.33
Biphenyl	43.90	39.50	35.15
2,6-Dimethylnaphthalene	57.20	45.20	39.48
Acenaphthene	78.10	46.00	46.50
Acenaphthylene	60.40	45.60	42.43
2,3,5-Trimethylnaphthalene	67.30	59.30	53.58
Fluorene	73.60	63.40	57.07
Dibenz(a,h)anthracene	78.50	54.70	63.23
Indeno(1,2,3-cd)pyrene	88.00	61.20	67.83
Phenanthrene	69.70	60.00	66.15
Anthracene	68.20	57.10	65.20
1-Methylphenanthrene	66.90	61.40	70.73
Flouranthene	94.50	78.80	77.22
Pyrene	100.70	89.50	83.53
Chrysene	86.60	64.30	78.25
Benz(a)anthracene	67.10	75.00	78.40
Benzo(b)fluoranthene	76.80	71.20	68.18
Benzo(k)fluoranthene	77.10	70.00	69.22
Benzo(ghi)perylene	81.80	54.70	63.43
Benzo(e)pyrene	76.60	70.90	69.10
Benzo(a)pyrene	74.60	92.50	70.17
Perylene	70.60	64.40	62.32

Table 3. Standard deviation, method detection limit and limit of quantitation - PAHs

Compound	SD	MDL (ng/μl)†	LOQ (ng/μl)†
Naphthalene	0.03	0.10	0.25
2-Methylnaphthalene	0.04	0.11	0.28
1-Methylnaphthalene	0.04	0.12	0.30
Biphenyl	0.05	0.15	0.38
2,6-Dimethylnaphthalene	0.04	0.14	0.35
Acenaphthene	0.04	0.14	0.35
Acenaphthylene	0.05	0.16	0.40
2,3,5-Trimethylnaphthalene	0.06	0.20	0.50
Fluorene	0.11	0.35	0.88
Dibenz(a,h)anthracene	0.19	0.59	1.48
Indeno(1,2,3-cd)pyrene	0.17	0.53	1.33
Phenanthrene	0.03	0.10	0.25
Anthracene	0.04	0.11	0.28
1-Methylphenanthrene	0.05	0.17	0.43
Flouranthene	0.03	0.08	0.20
Pyrene	0.03	0.08	0.20
Chrysene	0.03	0.09	0.23
Benz(a)anthracene	0.03	0.08	0.20
Benzo(b)fluoranthene	0.06	0.20	0.50
Benzo(k)fluoranthene	0.06	0.20	0.50
Benzo(ghi)perylene	0.18	0.57	1.43
Benzo(e)pyrene	0.06	0.19	0.48
Benzo(a)pyrene	0.06	0.19	0.48
Perylene	0.07	0.21	0.53

†The values are expressed in terms of microliter to represent the volume of the extract rather than sediment weight, since the weight of sediment taken for analysis varied over a large range, while the volume injected was always 1 microliter.

Table 4. Chlorinated hydrocarbons analyzed

Pesticides	PCBs	Congener No.
Aldrin	2,4'-CL2	8
Alpha-Chlordane (cis-chlordane)	2,2,5-CL3	18
2,4'-DDD (o,p'-TDE)	2,4,4'-CL3	28
4,4'-DDD (p,p'TDE)	2,2',3,5'-CL4	44
2,4'-DDE	2,2',5,5'-CL4	52
4,4'-DDE	2,3',4,4'-CL4	66
2,4'-DDT	3,3',4,4'-CL4	77
4,4'-DDT	2,2',4,5,5'-CL5	101
Dieldrin	2,3,3',4,4'-CL5	105
Heptachlor	2,3',4,4',5-CL5	118
Heptachlor epoxide	3,3',4,4',5-CL5	126
Hexachlorobenzene	2,2',3,3',4,4'-CL6	128
Lindane (gamma-BHC)	2,2',3,4,4',5-CL6	138
Mirex	2,2',4,4',5,5'-CL6	153
Trans-Nonachlor	2,2',3,3',4,4',5-CL7	170
Endrin	2,2',3,4,4',5,5'-CL7	180
	2,2',3,4',5,5',6-CL7	187
	2,2',3,3',4,4',5,6-CL8	195
	2,2',3,3',4,4',5,5',6-CL9	206
	Decachlorobiphenyl-CL10	209
 <u>Internal Standard</u>		
PCB BZ103		
 <u>Retention Time Markers</u>		
TCMX		
PCB BZ198		
 <u>Surrogates</u>		
DBOFB		
PCB BZ155		

Table 5. Matrix spike recovery of chlorinated hydrocarbons

Compound	Percent Compound Recovered				
	1	2	3	4	5
BZ8	68	65	45	42	40.89
Hexachlorobenzene	70	93	88	77	91.98
Lindane (gamma-BHC)	67	98	85	77	92.26
BZ18	68	129	101	90	81.55
BZ28	67	96	79	69	72.50
Heptachlor	71	85	113	83	89.16
BZ52	81	83	83	87	90.91
Aldrin	71	75	102	78	82.54
BZ44	87	84	104	94	89.05
Heptachlor epoxide	72	70	82	79	90.63
BZ66	87	83	97	93	104.65
2,4'-DDE	91	78	93	99	126.09
BZ101	96	82	97	99	114.25
Alpha-Chlordane	85	80	96	88	102.14
Trans-Nonachlor	85	80	96	88	99.04
Dieldrin	86	73	89	85	98.09
4,4'-DDE	82	76	91	85	94.82
BZ77	92	82	82	86	102.93
2,4'-DDD	119	103	119	114	141.42
Endrin	81	61	71	47	87.75
BZ118	86	83	101	90	101.68
4,4'-DDD	85	77	93	86	116.70
2,4'-DDT	81	76	90	81	105.60
BZ153	95	88	105	99	101.36
BZ105	83	77	92	86	93.51
4,4'-DDT	83	60	67	61	77.33
BZ138	88	81	95	90	107.25
BZ126	83	74	89	84	98.31
BZ187	89	80	96	91	94.06
BZ 128	86	84	94	88	95.78
BZ180	97	88	106	99	106.97
Mirex	87	80	96	88	101.95
BZ170	90	83	98	95	94.56
BZ195	89	78	97	91	92.37
BZ206	90	62	78	76	64.84
BZ209	87	79	95	90	88.93

Table 5. Matrix spike recovery of chlorinated hydrocarbons

Compound	Percent Compound Recovered		Average Recovery (%)
	6	7	
BZ8	integration messed up	31.13	48.67
Hexachlorobenzene	integration messed up	81.41	83.56
Lindane (gamma-BHC)	integration messed up	85.14	84.07
BZ18	integration messed up	78.75	91.38
BZ28	integration messed up	70.87	75.73
Heptachlor	integration messed up	80.94	87.02
BZ52	integration messed up	80.83	84.29
Aldrin	integration messed up	79.12	81.28
BZ44	integration messed up	90.69	91.46
Heptachlor epoxide	92.70	80.67	81.00
BZ66	97.23	90.75	93.23
2,4'-DDE	95.42	87.51	95.72
BZ101	88.78	83.75	94.40
Alpha-Chlordane	99.92	89.32	91.48
Trans-Nonachlor	100.50	91.63	91.45
Dieldrin	104.05	94.35	89.93
4,4'-DDE	114.28	99.31	91.77
BZ77	104.99	97.49	92.49
2,4'-DDD	145.46	134.22	125.16
Endrin	64.63	45.19	65.37
BZ118	95.39	86.75	91.97
4,4'-DDD	95.82	85.72	91.32
2,4'-DDT	88.89	87.37	87.12
BZ153	98.60	91.30	96.89
BZ105	84.01	76.92	84.64
4,4'-DDT	80.44	77.28	72.29
BZ138	118.93	93.11	96.18
BZ126	85.71	85.05	85.58
BZ187	85.98	82.53	88.37
BZ 128	88.51	82.69	88.43
BZ180	100.34	93.73	98.72
Mirex	89.57	88.22	90.11
BZ170	84.73	82.53	89.69
BZ195	85.00	84.17	88.08
BZ206	58.14	56.43	69.35
BZ209	84.03	81.74	86.53

Table 6. Standard deviation, method detection limit and limit of quantitation chlorinated hydrocarbons

Compound	RSD*	MDL** (pg/ μ l)†	LOQ*** (pg/ μ l)†
BZ8	14.53	11.21	28.03
Hexachlorobenzene	5.13	2.84	7.09
Lindane (gamma-BHC)	3.35	3.59	8.98
BZ18	11.15	8.13	20.34
BZ28	11.59	8.46	21.15
Heptachlor	3.82	3.78	9.44
BZ52	6.22	5.57	13.91
Aldrin	4.18	4.67	11.68
BZ44	5.97	5.19	12.97
Heptachlor epoxide	4.85	5.39	13.47
BZ66	4.35	3.58	8.95
2,4'-DDE	3.61	2.95	7.38
BZ101	3.86	2.95	7.38
Alpha-Chlordane	4.20	3.74	9.36
Trans-Nonachlor	3.74	3.65	9.14
Dieldrin	4.03	3.10	7.74
4,4'-DDE	3.46	3.19	7.99
BZ77	3.68	3.13	7.84
2,4'-DDD	4.06	3.38	8.46
Endrin	2.87	3.94	9.85
BZ118	3.61	2.88	7.21
4,4'-DDD	3.43	2.95	7.38
2,4'-DDT	1.79	1.77	4.43
BZ153	2.63	2.12	5.30
BZ105	2.91	2.79	6.97
4,4'-DDT	3.20	3.84	9.61
BZ138	6.34	3.65	9.13
BZ126	4.37	3.95	9.88
BZ187	3.41	2.94	7.35
BZ 128	2.37	1.90	4.76
BZ180	4.23	3.43	8.58
Mirex	4.11	3.67	9.19
BZ170	4.03	3.56	8.90
BZ195	4.61	1.90	4.75
BZ206	4.92	1.77	4.43
BZ209	5.67	1.90	4.75

*: Relative standard deviation

** : Method detection level (at 99% confidence level)

***: Limit of quantitation (at 99% confidence level)

† The values are expressed in terms of microliter to represent the volume of the extract rather than sediment weight, since the weight of sediment taken for analysis varied over a large range, while the volume injected was always 1 microliter.

Table 7. OSU-UCLA subcore intercalibration

Core No.	Depth (cm)	Pb-210		%H ₂ O		Time of deposition (A.D)	
		OSU	UCLA	OSU	UCLA	OSU	UCLA*
NOAA II	3-4	40.7 ± 0.9	30.5 ± 0.5	73.2	71.9	1947.81	1937
	5-6	19.7 ± 0.4	13.7 ± 0.3	72.4	68.2	1916.98	1903
NOAA III	5-6	12.3 ± 0.3	8.8 ± 0.2	56.1	54.9	1947.51	1932
	10-12	5.0 ± 0.2	5.2 ± 0.2	52.2	51.3	1896.75	1900
NOAA IV	1-2	38.1 ± 0.5	36.0 ± 0.8	61.4	61.0	1986.64	1984
	2-3	37.4 ± 0.5	36.5 ± 0.8	60.1	58.0	1985.15	1984
	3-4	32.9 ± 0.6	31.9 ± 0.7	57.1	56.2	1981.97	1980
	5-6	27.0 ± 0.5	26.1 ± 0.5	51.4	51.2	1974.60	1972
	7-8	18.9 ± 0.5	18.7 ± 0.4	47.2	46.8	1960.48	1960
NOAA VI	4-5	18.2 ± 0.6	16.9 ± 0.4	71.0	73.9	1905.36	1899

*Estimated by interpolating UCLA Pb-210 data into the OSU Pb-210 chronology

Table 8. Elemental Analysis (%TOC, %TON, C/N).

Subbottom Depth (cm)	%TOC	%TON	C/N
NOAA I			
0-1	2.29	0.27	8.43
1-2	2.23	0.26	8.66
2-3	2.24	0.25	8.81
3-4	2.19	0.26	8.58
4-5	2.07	0.24	8.49
5-6	1.91	0.23	8.45
6-7	1.84	0.22	8.42
7-8	1.80	0.21	8.40
8-9	1.75*	0.21*	8.52*
9-10	1.65	0.20	8.22
10-11	1.69	0.20	8.38
11-12	1.63	0.20	8.14
12-14	1.60	0.20	8.00
14-17	1.54	0.19	8.17
NOAA II			
0-0.5	4.71	0.58	8.07
0.5-1	4.22	0.51	8.23
1-1.5	4.41	0.52	8.50
1.5-2	4.81	0.57	8.50
2-2.5	4.38*	0.51*	8.65*
2.5-3	3.78	0.45	8.32
3-4	3.35	0.41	8.28
4-5	3.44	0.42	8.28
5-6	3.12	0.38	8.21
6-7	3.22	0.39	8.26
7-8	3.39	0.41	8.22
8-10	3.49	0.43	8.14
NOAA III			
0-1	2.04	0.26	7.91
1-2	2.26	0.27	8.32
2-3	2.11	0.27	7.91
3-4	2.13	0.26	8.06
4-5	2.16	0.27	7.92
5-6	2.10	0.26	8.19
6-7	1.99	0.25	8.00
7-8	2.07	0.26	7.87
8-10	1.88	0.24	7.87
10-12	2.05*	0.25*	8.37*
12-14	1.98	0.25	7.83

Table 8. Elemental Analysis (%TOC, %TON, C/N)

Subbottom Depth (cm)	%TOC	%TON	C/N
NOAA IV			
0-1	2.51	0.27	9.44
1-2	2.50	0.26	9.50
2-3	2.59	0.27	9.78
3-4	2.49	0.25	9.90
4-5	2.35	0.24	9.74
5-6	2.44*	0.24*	10.13*
6-7	2.21	0.22	10.03
7-8	2.02	0.21	9.53
8-9	1.99	0.21	9.56
9-10	1.66	0.18	9.20
10-11	1.68	0.20	8.65
11-12	1.42	0.17	8.61
12-14	1.26	0.14	9.00
NOAA V			
0-1	3.69	0.43	8.64
1-1.5	3.50	0.39	8.99
1.5-2	3.58	0.40	8.91
2-2.5	3.97	0.42	9.52
2.5-3	3.98	0.42	9.46
3-3.5	4.11	0.42	9.68
3.5-4	6.38	0.43	14.82
4-5	4.02	0.40	9.98
5-6	3.64	0.38	9.67
6-7	3.20	0.37	8.73
7-8	3.21*	0.36*	8.96*
NOAA VI			
0-0.5	3.20*	0.36*	8.79*
0.5-1	3.56	0.41	8.74
1-1.5	4.23	0.46	9.26
1.5-2	4.65	0.52	8.91
2-2.5	3.74	0.41	9.12
2.5-3	4.05	0.46	8.78
3-3.5	4.33	0.49	8.82
3.5-4	4.22	0.49	8.69
4-5	3.83	0.44	8.62
5-6	4.09	0.48	8.55

*Average of duplicate analyses.

Table 9a. Results of duplicate analysis for chlorinated hydrocarbons, NOAA IV, 10-11cm (ng/g)

Compound	10-11cm	10-11cm (Duplicate)
BZ8	2.21	1.84
Hexachlorobenzene	0.41	0.27
Lindane (gamma-BHC)	0.11	0.21
BZ18	3.36	2.19
BZ28	5.75	6.11
Heptachlor	nd	nd
BZ52	5.52	8.12
Aldrin	0.11	nd
BZ44	6.00	4.35
Heptachlor epoxide	nd	nd
BZ66	11.96	11.07
2,4'-DDE	239.58	216.24
BZ101	9.26	6.84
Alpha-Chlordane	2.42	1.13
Trans-Nonachlor	2.20	1.14
Dieldrin	nd	nd
4,4'-DDE	1763.84	1546.17
BZ77	19.44	16.30
2,4'-DDD	32.91	24.60
Endrin	nd	nd
BZ118	9.82	7.52
4,4'-DDD	183.63	155.06
2,4'-DDT	9.72	7.35
BZ153	8.86	6.81
BZ105	8.09	5.96
4,4'-DDT	153.33	114.82
BZ138	9.30	8.52
BZ126	nd	nd
BZ187	3.72	2.94
BZ 128	3.22	2.02
BZ180	5.56	4.21
Mirex	nd	0.73
BZ170	3.67	2.92
BZ195	0.90	1.09
BZ206	1.46	1.85
BZ209	1.54	1.04

nd: not detected

Table 9b. Results of duplicate analysis for chlorinated hydrocarbons, NOAA IV, 11-12cm (ng/g)

Compound	11-12cm	11-12cm Duplicate
BZ8	1.06	1.64
Hexachlorobenzene	0.22	0.12
Lindane (gamma-BHC)	0.13	0.08
BZ18	2.15	1.23
BZ28	2.99	2.83
Heptachlor	nd	nd
BZ52	3.41	6.92
Aldrin	nd	nd
BZ44	3.69	3.78
Heptachlor epoxide	nd	nd
BZ66	7.15	7.99
2,4'-DDE	98.37	136.74
BZ101	5.57	3.69
Alpha-Chlordane	0.78	0.39
Trans-Nonachlor	0.66	0.25
Dieldrin	nd	nd
4,4'-DDE	1754.41	1136.75
BZ77	14.41	8.80
2,4'-DDD	22.06	18.77
Endrin	nd	nd
BZ118	5.78	3.75
4,4'-DDD	87.43	138.32
2,4'-DDT	13.84	8.42
BZ153	4.65	3.37
BZ105	4.03	2.97
4,4'-DDT	90.02	94.55
BZ138	5.72	4.34
BZ126	nd	nd
BZ187	1.71	1.20
BZ 128	1.43	0.85
BZ180	3.12	3.28
Mirex	nd	nd
BZ170	1.77	1.24
BZ195	0.58	0.61
BZ206	0.95	0.49
BZ209	1.05	0.70

nd: not detected

Table 10. Results of duplicate analysis for PAHs, NOAA IV, 2-3cm (ng/g)

Compound	2-3cm	2-3cm (Duplicate)
Naphthalene	159.68	146.81
2-Methylnaphthalene	156.67	159.49
1-Methylnaphthalene	60.83	57.51
Biphenyl	78.14	61.13
2,6-Dimethylnaphthalene	133.20	104.67
Acenaphthene	nd	nd
Acenaphthylene	158.85	131.29
2,3,5-Trimethylnaphthalene	46.25	27.17
Fluorene	45.85	37.96
Dibenz(a,h)anthracene	188.40	180.72
Indeno(1,2,3-cd)pyrene	245.23	265.36
Phenanthrene	146.30	150.10
Anthracene	104.84	104.71
1-Methylphenanthrene	44.75	34.54
Flouranthene	224.97	247.30
Pyrene	315.61	343.00
Chrysene	166.52	170.62
Benz(a)anthracene	116.03	127.55
Benzo(b)fluoranthene	373.07	394.55
Benzo(k)fluoranthene	486.54	375.57
Benzo(ghi)perylene	392.13	454.28
Benzo(e)pyrene	253.40	289.44
Benzo(a)pyrene	308.69	418.83
Perylene	526.79	643.85

nd: not detected

Table 11a. PAHs in NOAA I (ng/g)

Pb-210 Date	1988-90	1982-85	1977-80
Compound	0-1cm	1-2cm	2-3cm
Naphthalene	25.03	25.36	35.83
2-Methylnaphthalene	29.18	33.18	35.10
1-Methylnaphthalene	11.79	10.92	13.07
Biphenyl	19.71	21.28	24.64
2,6-Dimethylnaphthalene	18.34	20.10	22.30
Acenaphthene	nd	1.91 †	2.42 †
Acenaphthylene	10.35	18.58	12.79
2,3,5-Trimethylnaphthalene	6.10 †	6.21	7.82
Fluorene	nd	6.15 †	4.84 †
Dibenz(a,h)anthracene	17.96	72.17	81.40
Indeno(1,2,3-cd)pyrene	64.51	104.32	89.52
Phenanthrene	39.12	30.33	32.25
Anthracene	14.88	13.70	19.62
1-Methylphenanthrene	11.93	2.88 †	2.85 †
Flouranthene	55.39	48.96	56.38
Pyrene	65.50	58.02	64.49
Chrysene	39.76	21.01	42.79
Benz(a)anthracene	27.33	48.42	49.47
Benzo(b)fluoranthene	44.75	37.88	55.29
Benzo(k)fluoranthene	70.79	76.45	106.55
Benzo(ghi)perylene	69.86	120.19	134.49
Benzo(e)pyrene	59.34	74.38	89.98
Benzo(a)pyrene	63.94	91.92	68.47
Perylene	111.42	96.97	122.00
Total PAHs	876.98	1041.31	1174.36

nd: not detected; below MDL

† Between MDL and LOQ

Table 11a. PAHs in NOAA I (ng/g)

Pb-210 Date	1972	1965	1957
Compound	3-4cm	4-5cm	5-6cm
Naphthalene	11.48	13.30	7.90
2-Methylnaphthalene	23.35	26.83	7.50
1-Methylnaphthalene	9.29	11.03	2.72
Biphenyl	17.08	19.39	5.44
2,6-Dimethylnaphthalene	17.43	19.98	8.66
Acenaphthene	nd	nd	nd
Acenaphthylene	10.99	11.87	5.87
2,3,5-Trimethylnaphthalene	6.27 †	7.05	1.47 †
Fluorene	nd	5.70 †	nd
Dibenz(a,h)anthracene	40.94	25.96	12.26
Indeno(1,2,3-cd)pyrene	60.84	83.01	27.31
Phenanthrene	30.58	35.48	14.58
Anthracene	13.69	12.94	7.25
1-Methylphenanthrene	6.85	7.86	9.04
Flouranthene	45.87	66.90	23.49
Pyrene	52.80	84.27	33.05
Chrysene	38.89	50.98	10.67
Benz(a)anthracene	33.30	36.48	18.28
Benzo(b)fluoranthene	45.09	51.96	19.67
Benzo(k)fluoranthene	64.85	84.93	27.60
Benzo(ghi)perylene	69.18	85.07	27.48
Benzo(e)pyrene	62.19	83.66	24.67
Benzo(a)pyrene	64.64	93.53	25.06
Perylene	75.55	100.35	35.76
Total PAHs	801.14	1018.52	355.72

nd: not detected; below MDL

† Between MDL and LOQ

Table 11a. PAHs in NOAA I (ng/g)

Pb-210 Date	1949	1941	1932
Compound	6-7cm	7-8cm	8-9cm
Naphthalene	7.73	9.65	12.90
2-Methylnaphthalene	10.93	10.48	10.35
1-Methylnaphthalene	4.50	4.83	4.55
Biphenyl	6.43	5.64 †	4.02 †
2,6-Dimethylnaphthalene	10.84	11.67	4.19 †
Acenaphthene	nd	nd	nd
Acenaphthylene	10.06	6.26 †	5.19
2,3,5-Trimethylnaphthalene	3.03 †	nd	nd
Fluorene	nd	nd	4.75 †
Dibenz(a,h)anthracene	14.88	32.43	14.32
Indeno(1,2,3-cd)pyrene	40.14	55.06	40.55
Phenanthrene	30.48	25.64	21.77
Anthracene	11.85	13.22	33.21
1-Methylphenanthrene	20.42	7.13	4.60 †
Flouranthene	47.12	42.95	35.16
Pyrene	66.95	54.51	45.08
Chrysene	27.65	26.43	25.31
Benz(a)anthracene	41.37	22.66	16.03
Benzo(b)fluoranthene	17.98	35.62	14.70
Benzo(k)fluoranthene	65.00	54.59	44.83
Benzo(ghi)perylene	43.75	68.02	48.91
Benzo(e)pyrene	45.09	51.98	31.24
Benzo(a)pyrene	45.01	56.63	28.74
Perylene	68.05	72.27	53.87
Total PAHs	639.24	667.66	504.27

nd: not detected; below MDL

† Between MDL and LOQ

Table 11a. PAHs in NOAA I (ng/g)

Pb-210 Date	1923	1913	1903
Compound	9-10cm	10-11cm	11-12cm
Naphthalene	nd	14.86	6.49
2-Methylnaphthalene	4.45 †	13.11	5.10 †
1-Methylnaphthalene	3.06 †	4.12 †	2.92 †
Biphenyl	3.50 †	4.30 †	nd
2,6-Dimethylnaphthalene	8.94	9.52	4.40 †
Acenaphthene	nd	nd	nd
Acenaphthylene	5.12 †	5.62 †	nd
2,3,5-Trimethylnaphthalene	4.39 †	nd	nd
Fluorene	nd	13.91	nd
Dibenz(a,h)anthracene	32.57	18.79	25.74
Indeno(1,2,3-cd)pyrene	70.01	49.67	59.03
Phenanthrene	31.62	33.64	17.89
Anthracene	12.35	84.70	9.62
1-Methylphenanthrene	8.97	12.05	7.04
Flouranthene	58.85	32.40	31.96
Pyrene	71.54	41.38	38.54
Chrysene	28.81	19.39	15.28
Benz(a)anthracene	24.50	18.54	19.74
Benzo(b)fluoranthene	23.58	15.60	19.29
Benzo(k)fluoranthene	61.25	32.46	41.66
Benzo(ghi)perylene	86.28	48.01	57.42
Benzo(e)pyrene	59.59	42.62	45.91
Benzo(a)pyrene	51.58	43.86	27.31
Perylene	100.21	69.26	76.99
Total PAHs	751.19	627.82	512.34

nd: not detected; below MDL

† Between MDL and LOQ

Table 11a. PAHs in NOAA I (ng/g)

Pb-210 Date	1889
Compound	12-14 cm
Naphthalene	6.16
2-Methylnaphthalene	3.87 †
1-Methylnaphthalene	1.94 †
Biphenyl	nd
2,6-Dimethylnaphthalene	3.76 †
Acenaphthene	nd
Acenaphthylene	2.45 †
2,3,5-Trimethylnaphthalene	nd
Fluorene	nd
Dibenz(a,h)anthracene	9.58 †
Indeno(1,2,3-cd)pyrene	26.15
Phenanthrene	16.81
Anthracene	29.96
1-Methylphenanthrene	3.08 †
Flouranthene	17.93
Pyrene	20.79
Chrysene	12.90
Benz(a)anthracene	10.70
Benzo(b)fluoranthene	13.52
Benzo(k)fluoranthene	26.42
Benzo(ghi)perylene	31.64
Benzo(e)pyrene	24.21
Benzo(a)pyrene	15.40
Perylene	49.40
Total PAHs	326.65

nd: not detected; below MDL

† Between MDL and LOQ

Table 11b. PAHs in NOAA II (ng/g)

Pb-210 Date	1990	1985	1979
Compound	0-0.5cm	0.5-1cm	1-1.5cm
Naphthalene	30.97	21.28	nd
2-Methylnaphthalene	23.17	18.08	23.76
1-Methylnaphthalene	12.49	12.11	13.59
Biphenyl	nd	nd	nd
2,6-Dimethylnaphthalene	16.22	14.95	nd
Acenaphthene	nd	nd	nd
Acenaphthylene	nd	nd	nd
2,3,5-Trimethylnaphthalene	nd	nd	nd
Fluorene	nd	nd	nd
Dibenz(a,h)anthracene	nd	41.82	36.49
Indeno(1,2,3-cd)pyrene	77.01	119.79	98.64
Phenanthrene	40.13	46.17	41.55
Anthracene	15.39	15.24	10.32
1-Methylphenanthrene	nd	24.44	19.02
Flouranthene	68.94	63.19	71.47
Pyrene	65.78	58.34	70.34
Chrysene	39.75	38.10	50.04
Benz(a)anthracene	27.14	24.20	29.57
Benzo(b)fluoranthene	54.59	49.83	36.92
Benzo(k)fluoranthene	78.66	92.77	97.12
Benzo(ghi)perylene	89.09 †	121.83	104.40
Benzo(e)pyrene	70.25	76.97	65.87
Benzo(a)pyrene	78.71	86.28	62.70
Perylene	71.84	114.16	112.01
Total PAHs	860.14	1039.55	943.81

nd: not detected; below MDL

† Between MDL and LOQ

Table 11b. PAHs in NOAA II (ng/g)

Pb-210 Date	1972	1966	1959
Compound	1.5-2cm	2-2.5cm	2.5-3cm
Naphthalene	33.31	33.65	21.36
2-Methylnaphthalene	28.30	24.07	15.09
1-Methylnaphthalene	14.87	14.56	10.76
Biphenyl	8.38 †	7.36 †	4.34 †
2,6-Dimethylnaphthalene	18.04	14.99	10.77
Acenaphthene	nd	nd	nd
Acenaphthylene	8.81 †	8.33 †	5.42 †
2,3,5-Trimethylnaphthalene	nd	10.19	9.42 †
Fluorene	nd	nd	9.47 †
Dibenz(a,h)anthracene	41.78	45.22	29.94
Indeno(1,2,3-cd)pyrene	91.77	84.98	83.50
Phenanthrene	42.20	68.07	67.68
Anthracene	13.15	17.71	15.01
1-Methylphenanthrene	15.48	23.70	21.44
Flouranthene	71.34	86.63	103.73
Pyrene	67.52	90.90	127.07
Chrysene	55.79	64.48	55.40
Benz(a)anthracene	41.38	40.41	42.16
Benzo(b)fluoranthene	42.17	50.38	48.79
Benzo(k)fluoranthene	76.60	87.44	74.96
Benzo(ghi)perylene	100.28	112.57	101.40
Benzo(e)pyrene	68.52	74.98	54.49
Benzo(a)pyrene	62.78	92.69	75.20
Perylene	82.82	83.14	69.14
Total PAHs	985.28	1136.44	1056.55

nd: not detected; below MDL

† Between MDL and LOQ

Table 11b. PAHs in NOAA II (ng/g)

Pb-210 Date	1948	1933	1917
Compound	3-4 cm	4-5 cm	5-6 cm
Naphthalene	22.76	26.48	9.53
2-Methylnaphthalene	13.45	10.82	6.33
1-Methylnaphthalene	9.70	9.50	5.89
Biphenyl	5.58 †	4.77 †	2.60 †
2,6-Dimethylnaphthalene	8.70	6.18	4.23 †
Acenaphthene	nd	nd	nd
Acenaphthylene	6.04 †	2.99 †	nd
2,3,5-Trimethylnaphthalene	5.88 †	4.85 †	4.40 †
Fluorene	5.85 †	nd	nd
Dibenz(a,h)anthracene	16.82	nd	nd
Indeno(1,2,3-cd)pyrene	78.15	42.85	12.23 †
Phenanthrene	43.39	24.91	21.11
Anthracene	12.13	4.69	3.52 †
1-Methylphenanthrene	11.54	4.94 †	5.67 †
Flouranthene	67.79	41.06	17.42
Pyrene	77.04	51.64	21.44
Chrysene	37.15	15.26	11.75
Benz(a)anthracene	26.32	11.56	6.67
Benzo(b)fluoranthene	33.23	14.65	7.25 †
Benzo(k)fluoranthene	66.76	38.26	17.09
Benzo(ghi)perylene	84.84	49.59	16.80
Benzo(e)pyrene	46.30	23.56	11.75
Benzo(a)pyrene	51.17	27.77	11.14
Perylene	70.87	54.92	60.71
Total PAHs	801.47	471.26	257.55

nd: not detected; below MDL

† Between MDL and LOQ

Table 11b. PAHs in NOAA II (ng/g)

Pb-210 Date	1901
Compound	6-7cm
Naphthalene	17.52
2-Methylnaphthalene	11.07
1-Methylnaphthalene	10.25
Biphenyl	5.22 †
2,6-Dimethylnaphthalene	6.76
Acenaphthene	nd
Acenaphthylene	nd
2,3,5-Trimethylnaphthalene	5.00 †
Fluorene	nd
Dibenz(a,h)anthracene	nd
Indeno(1,2,3-cd)pyrene	nd
Phenanthrene	16.93
Anthracene	2.37 †
1-Methylphenanthrene	5.62 †
Flouranthene	6.76
Pyrene	13.05
Chrysene	3.96
Benz(a)anthracene	nd
Benzo(b)fluoranthene	4.67 †
Benzo(k)fluoranthene	11.21
Benzo(ghi)perylene	11.25 †
Benzo(e)pyrene	12.26
Benzo(a)pyrene	6.62
Perylene	58.55
Total PAHs	209.08

nd: not detected; below MDL

† Between MDL and LOQ

Table 11c. PAHs in NOAA III (ng/g)

Pb-210 Date	1987-90	1979-83	1971-75
Compound	0-1cm	1-2cm	2-3cm
Naphthalene	1.25 †	10.78	1.01 †
2-Methylnaphthalene	4.64	5.45	1.69 †
1-Methylnaphthalene	3.16 †	3.17	1.43 †
Biphenyl	nd	2.46 †	nd
2,6-Dimethylnaphthalene	6.04	4.38	3.18
Acenaphthene	4.47	nd	nd
Acenaphthylene	6.80	nd	1.60 †
2,3,5-Trimethylnaphthalene	6.76	nd	nd
Fluorene	18.42	nd	nd
Dibenz(a,h)anthracene	22.96	nd	9.33 †
Indeno(1,2,3-cd)pyrene	80.48	13.45	23.75
Phenanthrene	103.59	20.15	14.94
Anthracene	35.11	5.33	3.88
1-Methylphenanthrene	16.12	4.12	3.35 †
Flouranthene	130.39	38.77	16.84
Pyrene	101.99	49.73	21.70
Chrysene	54.32	18.96	11.66
Benz(a)anthracene	48.01	11.54	7.47
Benzo(b)fluoranthene	30.79	9.76	7.69
Benzo(k)fluoranthene	79.16	28.85	21.53
Benzo(ghi)perylene	71.02	19.78	32.14
Benzo(e)pyrene	46.13	17.72	16.86
Benzo(a)pyrene	61.49	17.16	15.33
Perylene	52.80	29.70	20.63
Total PAHs	985.90	311.23	236.01

nd: not detected; below MDL

† Between MDL and LOQ

Table 11c. PAHs in NOAA III (ng/g)

Pb-210 Date	1965	1956	1948
Compound	3-4cm	4-5cm	5-6cm
Naphthalene	31.36	4.02	13.36
2-Methylnaphthalene	5.39	nd	3.45
1-Methylnaphthalene	3.22	nd	2.56 †
Biphenyl	2.06 †	nd	nd
2,6-Dimethylnaphthalene	4.76	nd	2.72 †
Acenaphthene	nd	nd	nd
Acenaphthylene	nd	nd	nd
2,3,5-Trimethylnaphthalene	2.02	nd	nd
Fluorene	nd	nd	nd
Dibenz(a,h)anthracene	nd	nd	nd
Indeno(1,2,3-cd)pyrene	18.85	12.33	10.65 †
Phenanthrene	13.14	9.02	7.92
Anthracene	3.31	2.81 †	1.64 †
1-Methylphenanthrene	3.28 †	nd	2.07 †
Flouranthene	14.45	9.51	10.38
Pyrene	20.69	15.39	14.71
Chrysene	8.25	15.67	6.21
Benz(a)anthracene	6.01	4.32	5.70
Benzo(b)fluoranthene	6.09	6.85	7.50
Benzo(k)fluoranthene	16.88	12.62	11.75
Benzo(ghi)perylene	19.51	14.69	16.63
Benzo(e)pyrene	14.22	8.95	12.04
Benzo(a)pyrene	14.44	10.47	10.83
Perylene	18.78	19.00	23.60
Total PAHs	226.72	145.67	163.71

nd: not detected; below MDL

† Between MDL and LOQ

Table 11c. PAHs in NOAA III (ng/g)

Pb-210 Date	1939	1929	1916
Compound	6-7cm	7-8cm	8-10cm
Naphthalene	2.07 †	nd	1.74 †
2-Methylnaphthalene	nd	nd	nd
1-Methylnaphthalene	nd	nd	nd
Biphenyl	nd	nd	nd
2,6-Dimethylnaphthalene	nd	nd	nd
Acenaphthene	nd	nd	nd
Acenaphthylene	nd	nd	nd
2,3,5-Trimethylnaphthalene	nd	nd	nd
Fluorene	nd	nd	nd
Dibenz(a,h)anthracene	nd	nd	nd
Indeno(1,2,3-cd)pyrene	nd	nd	nd
Phenanthrene	4.39 †	2.39 †	1.54 †
Anthracene	nd	nd	nd
1-Methylphenanthrene	nd	nd	nd
Flouranthene	3.76	1.63 †	1.06 †
Pyrene	7.61	3.90	2.25
Chrysene	6.15	2.10 †	1.42 †
Benz(a)anthracene	3.89	3.21	1.18 †
Benzo(b)fluoranthene	nd	nd	nd
Benzo(k)fluoranthene	5.31 †	nd	nd
Benzo(ghi)perylene	nd	nd	nd
Benzo(e)pyrene	5.40 †	nd	nd
Benzo(a)pyrene	4.72 †	nd	nd
Perylene	14.22	8.90	5.50
Total PAHs	57.53	22.12	14.68

nd: not detected; below MDL

† Between MDL and LOQ

Table 11c. PAHs in NOAA III (ng/g)

Pb-210 Date	1876
Compound	12-14 cm
Naphthalene	1.68 †
2-Methylnaphthalene	0.83 †
1-Methylnaphthalene	nd
Biphenyl	nd
2,6-Dimethylnaphthalene	3.33
Acenaphthene	nd
Acenaphthylene	nd
2,3,5-Trimethylnaphthalene	nd
Fluorene	nd
Dibenz(a,h)anthracene	nd
Indeno(1,2,3-cd)pyrene	nd
Phenanthrene	2.40
Anthracene	nd
1-Methylphenanthrene	nd
Flouranthene	1.08 †
Pyrene	2.49
Chrysene	2.68
Benz(a)anthracene	0.93 †
Benzo(b)fluoranthene	nd
Benzo(k)fluoranthene	2.53 †
Benzo(ghi)perylene	nd
Benzo(e)pyrene	2.31 †
Benzo(a)pyrene	nd
Perylene	10.92
Total PAHs	31.19

nd: not detected; below MDL

† Between MDL and LOQ

Table 11d. PAHs in NOAA IV (ng/g)

Pb-210 Date	1990-91	1987-89	1984-86
Compound	0-1cm	1-2cm	2-3cm
Naphthalene	15.07	46.88	159.68
2-Methylnaphthalene	nd	35.79	156.67
1-Methylnaphthalene	nd	13.28	60.83
Biphenyl	nd	nd	78.14
2,6-Dimethylnaphthalene	nd	30.45	133.20
Acenaphthene	nd	nd	nd
Acenaphthylene	37.21	38.58	158.85
2,3,5-Trimethylnaphthalene	nd	nd	46.25
Fluorene	nd	nd	45.85
Dibenz(a,h)anthracene	248.22	103.86	188.40
Indeno(1,2,3-cd)pyrene	299.05	202.35	245.23
Phenanthrene	67.97	82.78	146.30
Anthracene	57.26	51.92	104.84
1-Methylphenanthrene	25.92	38.45	44.75
Flouranthene	81.79	127.09	224.97
Pyrene	109.73	158.34	315.61
Chrysene	118.85	115.13	166.52
Benz(a)anthracene	120.16	106.53	116.03
Benzo(b)fluoranthene	188.01	133.21	373.07
Benzo(k)fluoranthene	235.85	239.60	486.54
Benzo(ghi)perylene	279.29	213.18	392.13
Benzo(e)pyrene	216.11	141.89	253.40
Benzo(a)pyrene	212.63	152.12	308.69
Perylene	298.68	264.35	526.79
Total PAHs	2611.81	2295.80	4732.73

nd: not detected; below MDL

†. Between MDL and LOQ

Table.11d. PAHs in NOAA IV (ng/g)

Pb-210 Date	1982	1978	1975
Compound	3-4cm	4-5cm	5-6cm
Naphthalene	173.57	52.83	56.32
2-Methylnaphthalene	187.94	68.64	79.71
1-Methylnaphthalene	61.26	25.47	24.89
Biphenyl	65.76	19.06	30.95
2,6-Dimethylnaphthalene	116.94	51.88	42.22
Acenaphthene	16.37	nd	9.67
Acenaphthylene	114.30	83.40	71.10
2,3,5-Trimethylnaphthalene	18.55	nd	11.50
Fluorene	33.64	nd	11.18
Dibenz(a,h)anthracene	166.51	127.67	90.36
Indeno(1,2,3-cd)pyrene	410.15	238.47	183.57
Phenanthrene	143.03	77.19	64.38
Anthracene	89.46	86.63	59.08
1-Methylphenanthrene	26.17	13.42	12.41
Flouranthene	257.93	148.05	268.96
Pyrene	360.40	237.46	343.59
Chrysene	243.93	73.82	174.26
Benz(a)anthracene	227.24	151.29	159.30
Benzo(b)fluoranthene	187.24	181.47	91.30
Benzo(k)fluoranthene	488.35	370.03	238.70
Benzo(ghi)perylene	407.98	284.69	190.06
Benzo(e)pyrene	294.48	201.95	215.43
Benzo(a)pyrene	376.85	227.32	180.94
Perylene	509.07	362.90	259.13
Total PAHs	4977.11	3083.63	2869.00

nd: not detected; below MDL

† Between MDL and LOQ

Table 11d. PAHs in NOAA IV (ng/g)

Pb-210 Date	1970	1960	1950
Compound	6-7cm	7-8cm	8-9cm
Naphthalene	49.25	49.40	41.37
2-Methylnaphthalene	65.03	47.31	39.72
1-Methylnaphthalene	22.05	16.60	14.81
Biphenyl	25.92	23.04	14.17
2,6-Dimethylnaphthalene	32.67	40.55	27.28
Acenaphthene	4.67 †	6.17 †	4.02 †
Acenaphthylene	59.91	51.56	37.49
2,3,5-Trimethylnaphthalene	17.73	17.92	nd
Fluorene	16.86	16.87	13.88 †
Dibenz(a,h)anthracene	118.36	90.19	52.11
Indeno(1,2,3-cd)pyrene	189.74	129.80	111.92
Phenanthrene	74.41	65.30	55.90
Anthracene	39.16	37.42	27.88
1-Methylphenanthrene	32.32	16.57	25.07
Flouranthene	142.73	107.92	89.66
Pyrene	209.47	166.11	135.35
Chrysene	150.85	88.95	73.25
Benz(a)anthracene	10.77	72.13	52.93
Benzo(b)fluoranthene	102.08	137.25	56.34
Benzo(k)fluoranthene	222.48	173.24	122.04
Benzo(ghi)perylene	188.23	161.43	128.62
Benzo(e)pyrene	169.25	141.09	121.40
Benzo(a)pyrene	166.40	134.35	141.02
Perylene	262.37	190.78	166.95
Total PAHs	2372.68	1981.96	1553.20

nd: not detected; below MDL

† Between MDL and LOQ

Table 11d. PAHs in NOAA IV (ng/g)

Pb-210 Date	1939	1928	1917
Compound	9-10cm	10-11cm	11-12cm
Naphthalene	23.26	19.91	17.18
2-Methylnaphthalene	19.27	18.57	13.61
1-Methylnaphthalene	9.07	6.63 †	6.89
Biphenyl	18.25	nd	4.20 †
2,6-Dimethylnaphthalene	14.23	12.39	10.40
Acenaphthene	2.06 †	nd	nd
Acenaphthylene	19.57	18.33	17.74
2,3,5-Trimethylnaphthalene	nd	5.34 †	8.88
Fluorene	8.10 †	nd	7.61 †
Dibenz(a,h)anthracene	25.06	27.26	26.98
Indeno(1,2,3-cd)pyrene	57.83	73.72	76.84
Phenanthrene	36.23	37.04	41.08
Anthracene	15.53	21.04	18.69
1-Methylphenanthrene	9.88	12.17	19.31
Flouranthene	51.35	71.00	67.53
Pyrene	74.39	90.78	96.62
Chrysene	33.56	43.19	49.67
Benz(a)anthracene	42.43	44.51	35.53
Benzo(b)fluoranthene	37.41	32.49	32.52
Benzo(k)fluoranthene	74.46	96.59	88.28
Benzo(ghi)perylene	71.29	89.71	89.96
Benzo(e)pyrene	53.33	68.90	57.49
Benzo(a)pyrene	58.10	71.59	67.95
Perylene	77.32	91.98	83.34
Total PAHs	831.97	953.15	938.29

nd: not detected; below MDL

† Between MDL and LOQ

Table 11d. PAHs in NOAA IV (ng/g)

Pb-210 Date	1899
Compound	12-14 cm
Naphthalene	6.14
2-Methylnaphthalene	3.25
1-Methylnaphthalene	2.04 †
Biphenyl	nd
2,6-Dimethylnaphthalene	2.53 †
Acenaphthene	nd
Acenaphthylene	nd
2,3,5-Trimethylnaphthalene	nd
Fluorene	nd
Dibenz(a,h)anthracene	9.35 †
Indeno(1,2,3-cd)pyrene	19.08
Phenanthrene	11.34
Anthracene	5.18
1-Methylphenanthrene	4.27
Flouranthene	16.71
Pyrene	24.53
Chrysene	14.58
Benz(a)anthracene	12.75
Benzo(b)fluoranthene	11.19
Benzo(k)fluoranthene	30.93
Benzo(ghi)perylene	22.92
Benzo(e)pyrene	19.06
Benzo(a)pyrene	25.71
Perylene	31.63
Total PAHs	273.19

nd: not detected; below MDL

† Between MDL and LOQ

Table 11e. PAHs in NOAA V (ng/g)

Pb-210 Date	1989-91	1985	1981
Compound	0-1cm	1-1.5cm	1.5-2cm
Naphthalene	28.74	41.43	32.86
2-Methylnaphthalene	18.85	44.15	33.16
1-Methylnaphthalene	11.39	18.90	20.70
Biphenyl	6.39 †	20.19	nd
2,6-Dimethylnaphthalene	16.25	15.34 †	nd
Acenaphthene	nd	6.42	nd
Acenaphthylene	10.68 †	22.48	nd
2,3,5-Trimethylnaphthalene	8.23 †	13.59	nd
Fluorene	nd	nd	nd
Dibenz(a,h)anthracene	38.81	65.64	77.07
Indeno(1,2,3-cd)pyrene	77.61	128.17	157.11
Phenanthrene	39.64	43.67	46.04
Anthracene	23.67	33.42	45.41
1-Methylphenanthrene	17.63	14.32	nd
Flouranthene	61.01	70.26	69.93
Pyrene	70.08	84.97	99.82
Chrysene	26.29	65.87	96.43
Benz(a)anthracene	29.20	58.59	43.61
Benzo(b)fluoranthene	30.75	74.66	86.94
Benzo(k)fluoranthene	115.27	145.66	198.54
Benzo(ghi)perylene	93.86	115.53	126.18
Benzo(e)pyrene	77.40	99.12	108.35
Benzo(a)pyrene	89.26	114.63	86.07
Perylene	91.30	115.43	140.85
Total PAHs	982.30	1412.44	1469.06

nd: not detected; below MDL

† Between MDL and LOQ

Table 11e. PAHs in NOAA V (ng/g)

Pb-210 Date	1974-77	1970	1960
Compound	2-3cm	3-3.5cm	4-5cm
Naphthalene	40.73	43.48	143.64
2-Methylnaphthalene	53.54	43.65	84.01
1-Methylnaphthalene	33.53	20.45	234.88
Biphenyl	nd	nd	nd
2,6-Dimethylnaphthalene	27.41	26.42	462.50
Acenaphthene	nd	nd	nd
Acenaphthylene	nd	nd	nd
2,3,5-Trimethylnaphthalene	68.02	52.01	208.95
Fluorene	nd	nd	nd
Dibenz(a,h)anthracene	168.90	155.86	159.31
Indeno(1,2,3-cd)pyrene	238.40	186.73	353.97
Phenanthrene	180.71	45.28	207.21
Anthracene	136.89	16.47	81.84
1-Methylphenanthrene	51.08	11.34	232.48
Flouranthene	99.77	100.16	207.90
Pyrene	201.22	204.61	180.34
Chrysene	180.22	134.64	536.69
Benz(a)anthracene	68.22	104.73	132.89
Benzo(b)fluoranthene	121.16	75.18	322.80
Benzo(k)fluoranthene	352.76	251.46	236.91
Benzo(ghi)perylene	230.85	225.05	210.29
Benzo(e)pyrene	212.61	186.11	342.15
Benzo(a)pyrene	221.40	112.98	204.53
Perylene	397.44	301.78	340.64
Total PAHs	3084.87	2298.39	4883.91

nd: not detected ; below MDL

† Between MDL and LOQ

Table 11e. PAHs in NOAA V (ng/g)

Pb-210 Date	1942	1923	1902
Compound	5-6cm	6-7cm	7-8cm
Naphthalene	123.93	36.83	14.56
2-Methylnaphthalene	53.33	9.73	3.89 †
1-Methylnaphthalene	133.45	5.04 †	nd
Biphenyl	45.08	nd	nd
2,6-Dimethylnaphthalene	239.12	nd	4.80 †
Acenaphthene	nd	9.04 †	nd
Acenaphthylene	nd	11.65 †	10.06 †
2,3,5-Trimethylnaphthalene	157.29	13.68	nd
Fluorene	nd	nd	nd
Dibenz(a,h)anthracene	168.10	24.35	34.10
Indeno(1,2,3-cd)pyrene	185.58	78.86	65.81
Phenanthrene	127.09	43.81	26.52
Anthracene	62.45	20.88	16.15
1-Methylphenanthrene	241.75	21.86	5.81 †
Flouranthene	96.90	59.35	53.35
Pyrene	176.78	88.63	71.83
Chrysene	382.78	23.20	27.67
Benz(a)anthracene	158.88	45.80	29.19
Benzo(b)fluoranthene	74.56	30.23	30.55
Benzo(k)fluoranthene	311.59	84.03	68.10
Benzo(ghi)perylene	179.72	72.24	79.94
Benzo(e)pyrene	193.96	41.65	37.56
Benzo(a)pyrene	86.88	51.13	40.82
Perylene	231.67	46.07	56.21
Total PAHs	3430.90	818.05	676.93

nd: not detected; below MDL

† Between MDL and LOQ

Table 11.f. PAHs in NOAA VI (ng/g)

Pb-210 Date	1987	1984	1980
Compound	0-0.5cm	0.5-1cm	1-1.5cm
Naphthalene	8.13	8.80	8.59
2-Methylnaphthalene	3.95 †	7.75	8.63
1-Methylnaphthalene	3.76 †	4.41 †	4.46 †
Biphenyl	nd	3.20 †	nd
2,6-Dimethylnaphthalene	2.46 †	2.85 †	nd
Acenaphthene	nd	nd	nd
Acenaphthylene	5.96 †	6.63	10.95
2,3,5-Trimethylnaphthalene	nd	3.99 †	4.53 †
Fluorene	nd	nd	nd
Dibenz(a,h)anthracene	14.74 †	17.09	39.99
Indeno(1,2,3-cd)pyrene	29.95	31.04	72.29
Phenanthrene	18.17	20.38	27.80
Anthracene	9.98	10.42	14.65
1-Methylphenanthrene	8.91	6.68	9.37
Flouranthene	25.85	33.43	38.02
Pyrene	31.31	38.74	42.25
Chrysene	19.96	27.37	38.23
Benz(a)anthracene	15.07	18.27	31.05
Benzo(b)fluoranthene	21.81	17.12	22.33
Benzo(k)fluoranthene	43.86	39.29	70.26
Benzo(ghi)perylene	33.27	41.84	69.64
Benzo(e)pyrene	26.71	28.51	45.66
Benzo(a)pyrene	23.97	28.49	47.97
Perylene	28.25	34.03	52.08
Total PAHs	376.07	430.35	658.76

nd: not detected; below MDL

† Between MDL and LOQ

Table 11f. PAHs in NOAA VI (ng/g)

Pb-210 Date	1978	1975	1961
Compound	1.5-2cm	2-2.5cm	2.5-3cm
Naphthalene	24.49	11.96	7.39 †
2-Methylnaphthalene	15.02	7.67	6.67 †
1-Methylnaphthalene	8.81	4.72 †	8.06 †
Biphenyl	nd	nd	nd
2,6-Dimethylnaphthalene	6.06 †	5.51 †	10.55
Acenaphthene	nd	nd	nd
Acenaphthylene	12.45	6.30 †	13.79
2,3,5-Trimethylnaphthalene	nd	5.15 †	nd
Fluorene	nd	nd	nd
Dibenz(a,h)anthracene	25.04	13.88 †	34.60
Indeno(1,2,3-cd)pyrene	56.97	43.48	71.42
Phenanthrene	26.63	22.32	45.61
Anthracene	11.84	9.44	22.80
1-Methylphenanthrene	11.28	7.54 †	19.49
Flouranthene	37.60	34.07	65.65
Pyrene	44.67	45.66	90.33
Chrysene	32.85	27.19	52.85
Benz(a)anthracene	24.41	22.31	39.51
Benzo(b)fluoranthene	37.51	21.34	57.77
Benzo(k)fluoranthene	70.09	63.07	100.33
Benzo(ghi)perylene	51.97	48.50	92.42
Benzo(e)pyrene	40.35	35.05	66.40
Benzo(a)pyrene	39.86	34.59	62.25
Perylene	47.08	38.63	68.74
Total PAHs	624.97	508.39	936.61

nd: not detected; below MDL

† Between MDL and LOQ

Table 11f. PAHs in NOAA VI (ng/g)

Pb-210 Date	1946	1930	1905
Compound	3-3.5 cm	3.5-4 cm	4-5 cm
Naphthalene	37.41	22.30	nd
2-Methylnaphthalene	10.31	4.52 †	7.86
1-Methylnaphthalene	8.51 †	5.01 †	4.68 †
Biphenyl	nd	nd	nd
2,6-Dimethylnaphthalene	8.15 †	11.03 †	4.29 †
Acenaphthene	nd	nd	nd
Acenaphthylene	16.97	nd	nd
2,3,5-Trimethylnaphthalene	nd	nd	nd
Fluorene	nd	nd	31.12
Dibenz(a,h)anthracene	44.90	24.89 †	39.08
Indeno(1,2,3-cd)pyrene	89.48	76.56	81.68
Phenanthrene	62.98	47.76	67.03
Anthracene	19.34	28.63	31.00
1-Methylphenanthrene	24.23	18.76	62.69
Flouranthene	81.40	59.96	49.74
Pyrene	106.00	81.45	75.59
Chrysene	64.68	57.20	54.60
Benz(a)anthracene	47.78	46.90	33.84
Benzo(b)fluoranthene	51.77	27.38	36.80
Benzo(k)fluoranthene	112.66	98.76	74.94
Benzo(ghi)perylene	104.10	99.26	76.43
Benzo(e)pyrene	69.86	56.77	47.57
Benzo(a)pyrene	73.12	72.14	50.16
Perylene	77.17	62.09	57.78
Total PAHs	1110.79	901.37	886.86

nd: not detected; below MDL

† Between MDL and LOQ

Table 11f. PAHs in NOAA VI (ng/g)

Pb-210 Date	1889
Compound	5-6cm
Naphthalene	9.21
2-Methylnaphthalene	2.87 †
1-Methylnaphthalene	2.47 †
Biphenyl	nd
2,6-Dimethylnaphthalene	nd
Acenaphthene	nd
Acenaphthylene	4.19 †
2,3,5-Trimethylnaphthalene	nd
Fluorene	nd
Dibenz(a,h)anthracene	28.30
Indeno(1,2,3-cd)pyrene	59.32
Phenanthrene	25.62
Anthracene	12.82
1-Methylphenanthrene	8.89
Flouranthene	30.87
Pyrene	50.77
Chrysene	38.05
Benz(a)anthracene	21.49
Benzo(b)fluoranthene	23.21
Benzo(k)fluoranthene	45.14
Benzo(ghi)perylene	57.22
Benzo(e)pyrene	31.36
Benzo(a)pyrene	34.82
Perylene	51.19
Total PAHs	537.82

nd: not detected; below MDL

† Between MDL and LOQ

Table 12a. PCBs in NOAA I (ng/g)

Pb-210 Date	1988-90	1982-85	1977-80	1972
Compound	0-1cm	1-2cm	2-3cm	3-4cm
BZ8	1.44	1.87	0.67	2.97
BZ18	1.13	1.24	2.37	1.47
BZ28	3.02	1.01	1.89	2.59
BZ44	1.82	3.06	2.60	2.14
BZ52	2.33	2.25	2.44	2.31
BZ66	4.58	5.12	6.30	6.77
BZ77	9.74	13.64	9.30	7.32
BZ101	2.64	8.11	6.04	4.80
BZ105	3.23	3.46	4.11	4.34
BZ118	3.14	2.00	4.75	3.75
BZ126	nd	nd	nd	nd
BZ 128	1.54	0.68	1.96	1.73
BZ138	4.48	2.24	5.63	4.47
BZ153	4.14	4.43	4.77	5.21
BZ170	1.63	0.68	2.37	1.94
BZ180	2.15	1.07	2.88	2.51
BZ187	2.88	0.97	2.13	2.02
BZ195	0.40	0.27	1.02	0.68
BZ206	0.80	0.48	0.43	1.64
BZ209	0.65	0.38	0.71	1.36
Total PCBs	51.74	52.96	62.38	60.01
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	16.11	19.10	18.15	15.40
Non- and mono-ortho coplanar PCBs (% in total)	31	36	29	26

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12a. PCBS in NOAA I (ng/g)

Pb-210 Date	1965	1957	1949	1941
Compound	4-5cm	5-6cm	6-7cm	7-8cm
BZ8	nd	1.52	1.25	1.09
BZ18	2.06	3.57	1.65	0.99
BZ28	2.57	1.72	2.09	1.97
BZ44	2.58	2.42	2.37	2.20
BZ52	2.81	3.17	2.99	2.75
BZ66	7.71	8.41	7.63	6.32
BZ77	15.54	4.44	18.37	11.33
BZ101	6.69	4.07	5.43	5.53
BZ105	5.90	4.48	3.84	2.63
BZ118	7.28	5.97	6.16	5.31
BZ126	nd	nd	nd	nd
BZ 128	2.54	1.26	1.67	2.22
BZ138	9.47	6.05	7.57	5.96
BZ153	7.30	6.70	5.75	7.23
BZ170	3.12	1.26	1.50	0.88
BZ180	4.00	1.91	2.37	1.55
BZ187	3.19	1.81	2.49	1.68
BZ195	1.62	0.37	0.51	0.67
BZ206	0.64	0.73	0.97	0.52
BZ209	0.94	0.50	0.69	0.37
Total PCBs	85.96	60.35	75.30	61.19
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	28.72	14.89	28.38	19.27
Non- and mono-ortho coplanar PCBs (% in total)	33	25	38	31

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12a. PCBS in NOAA I (ng/g)

Pb-210 Date	1932	1923	1913	1903
Compound	8-9cm	9-10cm	10-11cm	11-12cm
BZ8	0.43	0.76	0.40	0.35†
BZ18	0.58	4.59	0.81	0.59
BZ28	0.92	0.87	0.69	0.52
BZ44	1.40	1.14	0.81	1.07
BZ52	1.66	3.24	1.38	1.10
BZ66	3.40	3.86	2.87	2.71
BZ77	2.35	6.84	3.89	3.85
BZ101	2.68	2.42	1.72	1.39
BZ105	1.51	1.19	1.49	1.41
BZ118	3.51	2.85	1.64	1.49
BZ126	nd	nd	nd	nd
BZ 128	0.78	0.84	0.50	0.54
BZ138	4.77	3.25	1.98	1.86
BZ153	2.79	4.88	2.12	2.03
BZ170	0.65	0.91	0.48	0.44
BZ180	1.06	1.46	0.72	0.69
BZ187	1.06	1.40	0.78	0.72
BZ195	0.20	0.39	0.14	0.18
BZ206	0.34	0.70	0.30	0.27
BZ209	0.26	0.40	0.21	0.21
Total PCBs	30.34	42.00	22.93	21.42
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	7.37	10.88	7.02	6.76
Non- and mono-ortho coplanar PCBs (% in total)	24	26	31	32

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12a. PCBS in NOAA I (ng/g)

Pb-210 Date	1889
Compound	12-14 cm
BZ8	0.22 †
BZ18	0.32
BZ28	2.16
BZ44	0.76
BZ52	0.91
BZ66	1.84
BZ77	1.05
BZ101	1.29
BZ105	0.88
BZ118	1.28
BZ126	nd
BZ 128	0.36
BZ138	1.48
BZ153	1.24
BZ170	0.36
BZ180	0.54
BZ187	0.48
BZ195	0.40
BZ206	0.22
BZ209	0.17
Total PCBs	15.97
Non- and mono-ortho coplanar PCBs (Total = 77, 105, and 118)*	3.21
Non- and mono-ortho coplanar PCBs (% in total)	20

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12b. PCBS in NOAA II (ng/g)

Pb-210 Date	1990	1985	1979	1972
Compound	0-0.5cm	0.5-1cm	1-1.5cm	1.5-2cm
BZ8	1.09	1.73	1.89	nd
BZ18	2.93	1.01	4.64	2.86
BZ28	nd	nd	1.14	1.14
BZ44	2.70	2.30	3.48	2.85
BZ52	2.18	1.39	2.63	2.66
BZ66	1.29	1.52	3.88	4.78
BZ77	3.31	3.01	7.21	9.29
BZ101	1.53	1.54	2.89	3.19
BZ105	1.48	1.81	3.93	5.08
BZ118	1.39	1.36	3.30	4.44
BZ126	nd	nd	nd	nd
BZ128	0.55	0.56	1.23	1.55
BZ138	2.13	2.06	5.20	5.93
BZ153	1.77	2.37	4.29	6.42
BZ170	3.07	0.82	1.79	1.92
BZ180	2.05	1.15	3.87	3.52
BZ187	0.83	0.96	1.63	2.35
BZ195	0.40	0.27	0.52	0.48
BZ206	0.85	0.60	0.99	0.95
BZ209	0.96	0.48	0.85	0.47
Total PCBs	30.54	24.94	55.35	59.88
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	6.19	6.18	14.44	18.81
Non- and mono-ortho coplanar PCBs (% in total)	20	25	26	31

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12b. PCBS in NOAA-II (ng/g)

Pb-210 Date	1966	1959	1948	1933
Compound	2-2.5cm	2.5-3cm	3-4cm	4-5cm
BZ8	nd	nd	nd	nd
BZ18	2.00	0.64	2.00	1.39
BZ28	1.11	nd	nd	0.29
BZ44	1.96	0.59	0.62	0.43
BZ52	2.73	1.55	nd	2.07
BZ66	3.38	1.13	0.22	0.17
BZ77	1.62	nd	nd	0.36
BZ101	4.43	1.52	0.24	0.09 †
BZ105	3.59	1.29	0.33	0.21
BZ118	4.88	1.27	0.01	0.20
BZ126	nd	nd	nd	nd
BZ128	1.55	0.45	0.05 †	nd
BZ138	8.90	1.38	nd	0.43
BZ153	5.25	1.45	0.37	0.26
BZ170	4.58	1.16	0.15	0.17
BZ180	3.82	0.97	0.10	0.23
BZ187	2.80	0.83	nd	nd
BZ195	4.35	0.66	0.06 †	0.14
BZ206	1.44	0.71	0.11	0.13
BZ209	1.05	0.85	0.14	0.16
Total PCBs	59.44	16.44	4.39	6.72
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	10.09	2.55	0.34	0.77
Non- and mono-ortho coplanar PCBs (% in total)	17	16	8	11

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12b. PCBS in NOAA II.(ng/g)

Pb-210 Date	1917	1901
Compound	5-6 cm	6-7 cm
BZ8	nd	nd
BZ18	1.23	1.44
BZ28	0.19 †	nd
BZ44	0.34	nd
BZ52	nd	nd
BZ66	nd	nd
BZ77	nd	nd
BZ101	0.08 †	0.09 †
BZ105	0.12	0.15
BZ118	0.05 †	0.10
BZ126	nd	nd
BZ128	0.06 †	nd
BZ138	nd	nd
BZ153	0.22	0.24
BZ170	0.18	0.19
BZ180	0.21	nd
BZ187	nd	nd
BZ195	0.13	0.13
BZ206	0.10	0.11
BZ209		nd
Total PCBs	2.91	2.44
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	0.17	0.25
Non- and mono-ortho coplanar PCBs (% in total).	6	10

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12c. PCBs in NOAA III.(ng/g)

Pb-210 Date	1987-90	1979-83	1971-75	1965
Compound	0-1cm	1-2cm	2-3cm	3-4cm
BZ8	0.13†	nd	nd	nd
BZ18	0.92	0.80	0.78	0.38
BZ28	nd	nd	nd	nd
BZ44	0.55	0.23	0.38	0.16
BZ52	2.42	1.23	0.86	0.62
BZ66	0.52	0.45	0.34	0.34
BZ77	nd	0.60	nd	nd
BZ101	0.52	0.40	0.36	0.39
BZ105	0.73	0.64	0.59	0.34
BZ118	0.47	0.30	0.43	0.35
BZ126	nd	nd	nd	nd
BZ128	0.20	0.18	nd	0.10
BZ138	0.52	0.50	0.40	0.30
BZ153	1.30	0.56	0.75	0.32
BZ170	0.28	0.23	0.19	0.18
BZ180	0.46	0.41	0.35	0.26
BZ187	0.31	0.27	0.26	0.20
BZ195	0.08	0.18	nd	nd
BZ206	0.15	0.13	0.12	0.11
BZ209	0.10	0.10	0.09	0.15
Total PCBs	9.66	7.20	5.90	4.20
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	1.20	1.54	1.03	0.69
Non- and mono-ortho coplanar PCBs (% in total)	12	21	17	16

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12c. PCBs in NOAA III (ng/g)

Pb-210 Date	1956	1948	1939	1929
Compound	4-5cm	5-6cm	6-7cm	7-8cm
BZ8	0.15 †	nd	nd	0.18 †
BZ18	0.48	0.68	0.40	0.53
BZ28	nd	0.09 †	nd	0.14
BZ44	0.32	0.31	0.46	0.31
BZ52	0.92	0.68	0.90	0.62
BZ66	0.29	0.16	1.68	0.05
BZ77	nd	nd	nd	nd
BZ101	0.24	0.23	0.84	0.10
BZ105	0.17	0.16	0.11	0.09
BZ118	0.14	0.10	nd	0.11
BZ126	nd	nd	nd	nd
BZ128	0.10	0.06	nd	nd
BZ138	0.15	0.14	0.29	0.36
BZ153	0.11	0.28	0.17	0.21
BZ170	0.13	0.15	0.52	nd
BZ180	0.23	0.09	0.10	0.09
BZ187	0.15	0.09	0.10	nd
BZ195	nd	nd	nd	0.12
BZ206	0.13	nd	nd	0.03
BZ209	0.08	nd	nd	0.04
Total PCBs	3.79	3.21	5.57	3.00
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	0.31	0.26	0.11	0.21
Non- and mono-ortho coplanar PCBs (% in total)	8	8	2	7

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12c. PCBs in NOAA III. (ng/g)

Pb-210 Date	1916	1876
Compound	8-10cm	12-14cm
BZ8	nd	0.29 †
BZ18	0.14	0.24
BZ28	nd	0.04
BZ44	0.33	nd
BZ52	nd	0.10
BZ66	0.05	0.01
BZ77	nd	nd
BZ101	0.04	nd
BZ105	0.03	0.04
BZ118	0.05	0.03
BZ126	nd	nd
BZ128	nd	nd
BZ138	0.03 †	nd
BZ153	0.04	0.07
BZ170	0.04	nd
BZ180	0.02	nd
BZ187	nd	nd
BZ195	0.04	0.03
BZ206	0.03	nd
BZ209	0.04	nd
Total PCBs	0.88	0.86
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	0.07	0.07
Non- and mono-ortho coplanar PCBs (% in total)	8	8

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12d. PCBs in NOAA IV (ng/g)

Pb-210 Date	1990-91	1987-89	1984-86	1982
Compound	0-1cm	1-2cm	2-3cm	3-4cm
BZ8	nd	1.68	3.79	1.94
BZ18	4.24	3.57	4.02	2.00
BZ28	3.96	3.10	1.52	5.05
BZ52	13.75	8.88	15.62	11.31
BZ44	9.57	3.01	9.19	9.70
BZ66	18.60	25.04	36.59	30.99
BZ77	50.69	12.46	20.02	46.69
BZ101	17.97	11.04	17.48	20.47
BZ105	10.91	14.20	24.57	17.16
BZ118	18.35	13.18	21.32	18.54
BZ126	nd	0.16	nd	nd
BZ128	3.27	2.34	3.42	3.74
BZ138	19.72	14.58	23.73	18.73
BZ153	12.99	17.32	29.95	20.75
BZ170	5.39	3.66	5.14	6.32
BZ180	11.82	8.06	12.35	10.93
BZ187	5.17	4.21	6.57	5.52
BZ195	1.25	2.18	1.14	1.96
BZ206	2.53	1.54	2.16	2.85
BZ209	1.94	1.13	1.57	2.10
Total PCBs	212.12	151.34	240.13	236.74
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	79.96	39.84	65.91	82.39
Non- and mono-ortho coplanar PCBs (% in total)	38	26	27	35

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12d. PCBs in NOAA IV (ng/g)

Pb-210 Date	1978	1975	1970	1960
Compound	4-5cm	5-6cm	6-7cm	7-8cm
BZ8	1.14	1.61	6.82	6.65
BZ18	3.52	2.46	5.76	5.35
BZ28	1.87	1.83	10.13	8.98
BZ52	8.77	22.66	18.54	13.84
BZ44	5.61	16.45	15.75	13.70
BZ66	21.71	49.37	41.57	32.51
BZ77	11.93	31.77	70.34	52.82
BZ101	10.38	30.58	28.68	20.76
BZ105	12.26	28.35	25.16	19.21
BZ118	12.26	32.74	32.30	24.91
BZ126	nd	nd	nd	nd
BZ128	2.47	5.31	7.60	6.15
BZ138	13.03	34.71	32.34	22.14
BZ153	14.11	33.19	27.91	20.76
BZ170	3.04	6.81	11.33	0.49
BZ180	6.23	14.70	16.68	12.61
BZ187	4.20	8.43	9.88	7.91
BZ195	0.67	1.30	3.16	3.06
BZ206	1.15	2.08	6.14	0.64
BZ209	0.82	1.38	4.19	1.69
Total PCBs	135.17	325.72	374.28	274.20
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	36.45	92.86	127.81	96.94
Non- and mono-ortho coplanar PCBs (% in total)	27	29	34	35

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12d. PCBs in NOAA IV (ng/g)

Pb-210 Date	1950	1939	1928	1917
Compound	8-9cm	9-10cm	10-11cm	11-12cm
BZ8	2.15	1.53	2.21	1.06
BZ18	4.39	2.06	3.36	2.15
BZ28	6.86	2.68	5.75	2.99
BZ52	15.31	3.82	5.52	3.41
BZ44	11.55	4.13	6.00	3.69
BZ66	36.75	8.96	11.96	7.15
BZ77	18.34	14.56	19.44	14.41
BZ101	22.42	6.44	9.26	5.57
BZ105	15.96	5.98	8.09	4.03
BZ118	22.14	7.35	9.82	5.78
BZ126	nd	nd	nd	nd
BZ128	3.65	2.06	3.22	1.43
BZ138	25.74	7.16	9.30	5.72
BZ153	20.31	6.45	8.86	4.65
BZ170	5.12	2.84	3.67	1.77
BZ180	10.42	4.29	5.56	3.12
BZ187	6.54	2.51	3.72	1.71
BZ195	1.03	0.39	0.90	0.58
BZ206	2.15	0.78	1.46	0.95
BZ209	1.62	0.90	1.54	1.05
Total PCBs	232.45	84.91	119.61	71.21
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	56.44	27.89	37.35	24.21
Non- and mono-ortho coplanar PCBs (% in total)	24	33	31	34

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12d. PCBs in NOAA IV (ng/g)

Pb-210 Date	1899
Compound	12-14 cm
BZ8	0.37
BZ18	0.64
BZ28	1.50
BZ52	1.54
BZ44	1.17
BZ66	2.15
BZ77	1.55
BZ101	2.03
BZ105	1.49
BZ118	1.87
BZ126	0.05 †
BZ128	0.43
BZ138	2.03
BZ153	1.73
BZ170	0.42
BZ180	1.02
BZ187	0.56
BZ195	0.17
BZ206	0.17
BZ209	0.13
Total PCBs	21.03
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	4.91
Non- and mono-ortho coplanar PCBs (% in total)	23

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12e. PCBs in NOAA V (ng/g)

Pb-210 Date	1989-91	1985	1981	1974-77
Compound	0-1 cm	1-1.5 cm	1.5-2 cm	2-3 cm
BZ8	nd	nd	nd	1.61
BZ18	1.81	4.02	4.79	2.75
BZ28	0.52	0.79	1.70	9.20
BZ44	1.78	1.38	3.15	8.45
BZ52	1.67	1.44	4.04	8.14
BZ66	2.20	2.69	7.95	20.74
BZ77	4.34	8.49	14.68	34.85
BZ101	1.17	2.36	6.76	17.77
BZ105	1.79	2.68	7.18	15.31
BZ118	1.59	2.96	7.90	21.10
BZ126	nd	nd	nd	nd
BZ128	0.86	0.76	1.62	3.84
BZ138	3.47	4.34	11.45	29.44
BZ153	2.14	3.35	8.11	20.13
BZ170	2.22	1.09	2.49	5.89
BZ180	2.91	2.18	5.66	11.09
BZ187	1.76	1.49	2.59	7.57
BZ195	0.30	0.26	0.54	1.29
BZ206	0.58	0.56	1.27	2.72
BZ209	0.49	0.57	1.19	1.82
Total PCBs	31.60	41.41	93.08	223.71
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	7.72	14.13	29.76	71.26
Non- and mono-ortho coplanar PCBs (% in total)	24	34	32	32

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12e. PCBs in NOAA V (ng/g)

Pb-210 Date	1970	1960	1942	1923
Compound	3-3.5cm	4-5cm	5-6cm	6-7cm
BZ8	nd	24.81	16.44	3.42
BZ18	4.53	18.24	16.89	nd
BZ28	2.09	nd	nd	nd
BZ44	5.58	nd	nd	0.22 †
BZ52	7.35	19.48	33.68	1.39
BZ66	15.76	10.73	6.13	0.27 †
BZ77	10.71	nd	nd	nd
BZ101	10.99	8.39	5.34	1.11
BZ105	11.18	1.92	nd	0.13 †
BZ118	13.89	6.48	1.01	0.15 †
BZ126	nd	nd	nd	nd
BZ128	2.37	1.28	1.01	0.13 †
BZ138	15.74	4.19	1.34	0.34
BZ153	7.53	0.74	0.71	0.26
BZ170	4.23	4.70	3.39	0.34
BZ180	9.17	4.69	5.41	0.33
BZ187	7.41	1.82	1.87	nd
BZ195	nd	nd	nd	0.75
BZ206	2.36	3.93	3.83	0.72
BZ209	1.40	2.40	3.46	0.40
Total PCBs	132.27	113.80	100.51	9.96
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	35.78	8.40	1.01	0.29
Non- and mono-ortho coplanar PCBs (% in total)	27	7	1	3

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12e. PCBs in NOAA V (ng/g)

Pb-210 Date	1902
Compound	7-8 cm
BZ8	0.64
BZ18	0.54
BZ28	nd
BZ44	0.33 †
BZ52	1.29
BZ66	1.15
BZ77	nd
BZ101	0.33
BZ105	0.20 †
BZ118	0.19 †
BZ126	nd
BZ128	0.13 †
BZ138	0.24 †
BZ153	0.19
BZ170	0.17 †
BZ180	0.09
BZ187	nd
BZ195	0.07 †
BZ206	0.16
BZ209	0.21
Total PCBs	5.92
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	0.39
Non- and mono-ortho coplanar PCBs (% in total)	7

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12f. PCBs in NOAA VI (ng/g)

Pb-210 Date	1987	1984	1980	1978
Compound	0-0.5cm	0.5-1cm	1-1.5cm	1.5-2cm
BZ8	1.86	0.85	nd	nd
BZ18	1.21	1.61	2.16	1.36
BZ28	nd	nd	nd	nd
BZ44	0.98	0.81	1.58	1.27
BZ52	0.96	0.87	1.37	1.80
BZ66	1.37	1.12	2.45	2.16
BZ77	0.80	2.73	0.64	2.50
BZ101	0.69	1.12	1.34	2.09
BZ105	1.18	1.26	1.67	1.94
BZ118	1.14	1.29	2.24	3.78
BZ126	nd	nd	nd	nd
BZ128	0.35	0.51	0.64	1.04
BZ138	1.04	1.91	1.67	4.02
BZ153	1.45	1.47	1.91	2.56
BZ170	0.40	0.59	0.68	1.15
BZ180	0.67	1.19	1.29	2.11
BZ187	0.47	0.77	0.99	1.48
BZ195	0.11	0.15	0.17	0.28
BZ206	0.21	0.37	0.38	0.62
BZ209	0.22	0.32	0.31	0.46
Total PCBs	15.11	18.95	21.50	30.60
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	3.12	5.28	4.56	8.22
Non- and mono-ortho coplanar PCBs (% in total)	21	28	21	27

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12f. PCBs in NOAA VI (ng/g)

Pb-210 Date	1975	1961	1946	1930
Compound	2-2.5cm	2.5-3cm	3-3.5cm	3.5-4cm
BZ8	nd	1.11	nd	nd
BZ18	1.43	0.91	1.34	2.93
BZ28	1.63	0.63	1.04	1.63
BZ44	1.42	2.00	2.56	1.22
BZ52	1.46	1.71	1.84	1.93
BZ66	2.41	2.35	2.35	2.09
BZ77	1.81	4.69	7.16	1.40
BZ101	1.98	2.33	2.50	2.22
BZ105	2.03	2.42	2.61	2.28
BZ118	2.94	2.26	2.89	2.70
BZ126	nd	nd	nd	nd
BZ128	0.89	0.91	1.08	0.87
BZ138	3.52	2.69	3.13	3.34
BZ153	2.78	3.76	2.47	2.76
BZ170	0.87	1.08	1.23	1.10
BZ180	1.70	1.66	2.30	1.98
BZ187	1.41	1.49	1.62	1.58
BZ195	0.22	0.36	0.33	0.34
BZ206	0.48	0.63	0.91	0.87
BZ209	0.31	0.54	0.94	0.88
Total PCBs	29.30	33.53	38.30	32.11
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	6.78	9.37	12.66	6.38
Non- and mono-ortho coplanar PCBs (% in total)	23	28	33	20

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 12f. PCBs in NOAA VI (ng/g)

Pb-210 Date	1905	1889
Compound	4-5 cm	5-6 cm
BZ8	nd	0.20 †
BZ18	0.71	1.38
BZ28	0.63	nd
BZ44	1.16	0.60
BZ52	1.22	1.86
BZ66	1.82	0.47
BZ77	0.54	nd
BZ101	1.75	0.32
BZ105	1.32	0.53
BZ118	1.55	0.18
BZ126	nd	nd
BZ128	0.92	0.06 †
BZ138	2.10	0.28
BZ153	1.98	0.55
BZ170	0.89	0.11 †
BZ180	1.45	0.20
BZ187	1.55	0.24
BZ195	0.38	0.06 †
BZ206	0.61	0.09
BZ209	0.44	0.09 †
Total PCBs	21.02	7.22
Non- and mono-ortho coplanar PCBs (Total = 77, 105 and 118)*	3.41	0.71
Non- and mono-ortho coplanar PCBs (% in total)	16	10

nd: not detected; below MDL

† Between MDL and LOQ

*Note that BZ126 (non-ortho) was not detected by the current procedure in any of the sediment sample).

Table 13a. Pesticides in NOAA I (ng/g)

Pb-210 Date	1988-90	1982-85	1977-80	1972
Compound	0-1cm	1-2cm	2-3cm	3-4cm
Aldrin	0.16	0.27	0.27	0.29
Alpha-Chlordane	0.74	0.40	0.36	1.73
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	0.25	0.27	0.19	0.15
Lindane (gamma-BHC)	0.31	0.74	0.26	0.50
Heptachlor	0.09†	nd	0.08†	0.12
Heptachlor epoxide	0.49†	0.41	nd	nd
Mirex	nd	nd	nd	nd
Trans-Nonachlor	0.93	0.51	0.38	1.91
2,4'-DDE	57.36	64.36	92.52	39.75
4,4'-DDE	399.11	552.81	504.74	580.37
2,4'-DDD	5.20	10.39	7.23	5.75
4,4'-DDD	36.78	57.92	41.58	34.17
2,4'-DDT	3.16	1.59	1.99	2.27
4,4'-DDT	29.95	60.43	20.03	28.22
Total Pesticides	534.53	750.11	669.64	695.24
Total DDTs	531.55	747.50	668.09	690.53
%DDTs in Total Pesticides	99.44	99.65	99.77	99.32
2,4'-DDT/4,4'-DDT	0.11	0.03	0.10	0.08
2,4'- and 4,4'-DDE	13.79	9.95	27.12	20.34
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

na: not analyzed, possible
electronic interference

† Between MDL and LOQ

Table 13a. Pesticides in NOAA I (ng/g)

Pb-210 Date	1965	1957	1949	1941
Compound	4-5cm	5-6cm	6-7cm	7-8cm
Aldrin	na	0.36	0.29 †	0.11 †
Alpha-Chlordane	1.63	0.28	0.40	0.18
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	nd	0.51
Hexachlorobenzene	na	0.17 †	0.19 †	0.17
Lindane (gamma-BHC)	na	0.33	0.25	0.12 †
Heptachlor	na	nd	nd	nd
Heptachlor epoxide	nd	nd	0.23 †	nd
Mirex	nd	nd	nd	nd
Trans-Nonachlor	2.15	0.21 †	0.36	0.13 †
2,4'-DDE	186.59	76.88	105.45	87.32
4,4'-DDE	1105.48	641.99	754.98	689.32
2,4'-DDD	14.32	13.03	17.41	14.31
4,4'-DDD	220.73	64.97	82.07	80.43
2,4'-DDT	2.91	3.34	2.81	2.71
4,4'-DDT	92.36	96.97	71.80	34.08
Total Pesticides	1626.17	898.52	1036.23	909.40
Total DDTs	1622.39	897.17	1034.51	908.17
%DDTs in Total Pesticides	99.77	99.85	99.83	99.87
2,4'-DDT/4,4'-DDT	0.03	0.03	0.04	0.08
<u>2,4'- and 4,4'-DDE</u>	13.56	7.17	11.53	21.11
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

na: not analyzed, possible
electronic interference

† Between MDL and LOQ

Table 13b. Pesticides in NOAA II (ng/g)

Pb-210 Date	1990	1985	1979	1972
Compound	0-0.5cm	0.5-1cm	1-1.5cm	1.5-2cm
Aldrin	nd	1.17	1.33	1.11
Alpha-Chlordane	1.25	0.83	1.00	0.49 †
Dieldrin	0.50	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	nd	0.69	1.34	1.08
Lindane (gamma-BHC)	0.38	1.22	0.53	0.32
Heptachlor	nd	nd	nd	nd
Heptachlor epoxide	0.65	nd	nd	nd
Mirex	nd	nd	nd	nd
Trans-Nonachlor	1.26	0.84	1.06	0.36 †
2,4'-DDE	6.36	6.68	27.19	93.81
4,4'-DDE	88.75	120.41	325.02	670.42
2,4'-DDD	1.62	1.37	3.31	5.93
4,4'-DDD	6.48	5.77	20.60	44.23
2,4'-DDT	2.02	2.32	4.57	5.24
4,4'-DDT	5.06	3.01	10.94	16.08
Total Pesticides	114.33	144.30	396.88	839.08
Total DDTs	110.30	139.55	391.63	835.72
%DDTs in Total Pesticides	96.47	96.71	98.68	99.60
2,4'-DDT/4,4'-DDT	0.40	0.77	0.42	0.33
<u>2,4'- and 4,4'-DDE</u>	13.42	23.85	22.71	35.85
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13b. Pesticides in NOAA II (ng/g)

Pb-210 Date	1966	1959	1948	1933
Compound	2-2.5 cm	2.5-3 cm	3-4 cm	4-5 cm
Aldrin	0.39 †	nd	0.41	nd
Alpha-Chlordane	0.65	0.32	0.14 †	0.62
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	1.03	0.25	0.23	0.10 †
Lindane (gamma-BHC)	0.49	0.67	nd	nd
Heptachlor	nd	nd	nd	nd
Heptachlor epoxide	nd	nd	0.10	0.19
Mirex	nd	nd	nd	nd
Trans-Nonachlor	0.27 †	nd	nd	0.13 †
2,4'-DDE	79.75	29.75	1.02	0.87
4,4'-DDE	565.63	154.65	11.69	5.38
2,4'-DDD	28.92	70.96	5.15	0.66
4,4'-DDD	100.27	114.27	5.77	1.09
2,4'-DDT	30.25	115.61	4.66	nd
4,4'-DDT	93.73	207.89	35.51	nd
Total Pesticides	901.39	694.35	64.68	9.04
Total DDTs	898.55	693.12	63.80	8.01
%DDTs in Total Pesticides	99.69	99.82	98.64	88.54
2,4'-DDT/4,4'-DDT	0.32	0.56	0.13	
<u>2,4'- and 4,4'-DDE</u>	5.21	0.57	0.32	
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13b. Pesticides in NOAA II (ng/g)

Pb-210 Date	1917	1901
Compound	5-6cm	6-7cm
Aldrin	0.14	nd
Alpha-Chlordane	0.28	0.27
Dieldrin	nd	nd
Endrin	nd	nd
Hexachlorobenzene	0.24	0.09 †
Lindane (gamma-BHC)	nd	nd
Heptachlor	0.35	nd
Heptachlor epoxide	0.29	nd
Mirex	nd	nd
Trans-Nonachlor	nd	0.12 †
2,4'-DDE	0.65	0.55
4,4'-DDE	2.02	2.11
2,4'-DDD	0.19	0.17
4,4'-DDD	0.61	0.49
2,4'-DDT	nd	nd
4,4'-DDT	nd	nd
Total Pesticides	4.78	3.81
Total DDTs	3.47	3.33
%DDTs in Total Pesticides	72.64	87.20
2,4'-DDT/4,4'-DDT		
<u>2,4'- and 4,4'-DDE</u>		
2,4'- and 4,4'-DDT		

nd: not detected; below MDL

† Between MDL and LOQ

Table 13c. Pesticides in NOAA III (ng/g)

Pb-210 Date	1987-90	1979-83	1971-75	1965
Compound	0-1cm	1-2cm	2-3cm	3-4cm
Aldrin	nd	nd	0.21	nd
Alpha-Chlordane	0.24	0.15	0.11	0.14
Dieldrin	nd	0.31	0.25	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	0.11 †	0.33	0.21	nd
Lindane (gamma-BHC)	nd	0.07 †	0.08 †	nd
Heptachlor	0.40	0.06 †	0.06 †	0.27
Heptachlor epoxide	nd	nd	nd	nd
Mirex	0.07 †	0.04 †	0.04 †	nd
Trans-Nonachlor	0.28	0.10 †	0.73	nd
2,4'-DDE	13.18	11.73	15.70	10.94
4,4'-DDE	60.15	56.84	89.38	43.96
2,4'-DDD	7.34	8.87	15.98	16.74
4,4'-DDD	36.37	20.87	44.77	37.34
2,4'-DDT	13.89	8.57	17.42	30.23
4,4'-DDT	205.34	16.22	139.68	54.84
Total Pesticides	337.35	124.17	324.62	194.46
Total DDTs	336.26	123.11	322.94	194.05
%DDTs in Total Pesticides	99.68	99.14	99.48	99.79
2,4'-DDT/4,4'-DDT	0.07	0.53	0.12	0.55
<u>2,4'- and 4,4'-DDE</u>	0.33	2.77	0.67	0.65
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13c. Pesticides in NOAA III (ng/g)

Pb-210 Date	1956	1948	1939	1929
Compound	4-5cm	5-6cm	6-7cm	7-8cm
Aldrin	0.33	0.28	nd	nd
Alpha-Chlordane	0.08 †	0.10 †	0.41	0.32
Dieldrin	0.09 †	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	nd	nd	nd	nd
Lindane (gamma-BHC)	0.05 †	nd	nd	nd
Heptachlor	nd	nd	nd	0.19
Heptachlor epoxide	nd	nd	nd	nd
Mirex	0.08 †	nd	nd	nd
Trans-Nonachlor	0.10 †	nd	nd	0.05 †
2,4'-DDE	9.51	1.48	1.96	0.82
4,4'-DDE	30.23	17.69	14.63	2.08
2,4'-DDD	25.86	7.57	2.55	1.19
4,4'-DDD	41.77	27.13	5.73	2.18
2,4'-DDT	91.44	24.66	3.17	1.11
4,4'-DDT	195.44	87.43	1.43	2.13
Total Pesticides	394.98	166.33	29.88	10.07
Total DDTs	394.25	165.96	29.47	9.51
%DDTs in Total Pesticides	99.82	99.77	98.63	94.38
2,4'-DDT/4,4'-DDT	0.47	0.28	2.22	0.52
<u>2,4'- and 4,4'-DDE</u>	0.14	0.17	3.61	0.89
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13c. Pesticides in NOAA III (ng/g)

Pb-210 Date	1916	1876
Compound	8-10cm	12-14cm
Aldrin	nd	nd
Alpha-Chlordane	0.05 †	0.08 †
Dieldrin	nd	nd
Endrin	nd	nd
Hexachlorobenzene	0.14	0.10 †
Lindane (gamma-BHC)	nd	nd
Heptachlor	nd	nd
Heptachlor epoxide	nd	nd
Mirex	nd	nd
Trans-Nonachlor	nd	0.07 †
2,4'-DDE	0.32	0.19
4,4'-DDE	1.35	0.40
2,4'-DDD	0.29	0.11
4,4'-DDD	0.77	0.24
2,4'-DDT	0.10	0.04
4,4'-DDT	0.35	0.11
Total Pesticides	3.37	1.34
Total DDTs	3.17	1.09
%DDTs in Total Pesticides	94.22	81.40
2,4'-DDT/4,4'-DDT	0.27	0.40
<u>2,4'- and 4,4'-DDE</u>	3.69	3.86
2,4'- and 4,4'-DDT		

nd: not detected; below MDL

† Between MDL and LOQ

Table 13d. Pesticides in NOAA IV. (ng/g)

Pb-210 Date	1950	1939	1928	1917
Compound	8-9cm	9-10cm	10-11cm	11-12cm
Aldrin	0.38	nd	0.11	nd
Alpha-Chlordane	1.32	1.44	2.42	0.78
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	nd	0.20	0.41	0.22
Lindane (gamma-BHC)	0.63	0.09 †	0.11 †	0.13 †
Heptachlor	nd	nd	nd	nd
Heptachlor epoxide	nd	nd	nd	nd
Mirex	0.31	nd	nd	nd
Trans-Nonachlor	1.03	1.43	2.20	0.66
2,4'-DDE	323.00	184.53	239.58	98.37
4,4'-DDE	3089.12	1665.35	1763.84	1754.41
2,4'-DDD	81.16	27.88	32.91	22.06
4,4'-DDD	251.33	177.91	183.63	87.43
2,4'-DDT	18.98	16.15	9.72	13.84
4,4'-DDT	147.83	246.67	153.33	90.02
Total Pesticides	3915.10	2321.65	2388.26	2067.92
Total DDTs	3911.43	2318.49	2383.01	2066.12
%DDTs in Total Pesticides	99.91	99.86	99.78	99.91
2,4'-DDT/4,4'-DDT	0.13	0.07	0.06	0.15
<u>2,4'- and 4,4'-DDE</u>	20.46	7.04	12.29	17.84
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13d. Pesticides in NOAA IV (ng/g)

Pb-210 Date	1978	1975	1970	1960
Compound	4-5cm	5-6cm	6-7cm	7-8cm
Aldrin	nd	0.24	0.16	0.14 †
Alpha-Chlordane	1.18	2.16	2.19	1.58
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	5.37	nd
Hexachlorobenzene	0.47	0.28	0.76	0.67
Lindane (gamma-BHC)	0.45	0.13 †	0.30	0.30
Heptachlor	nd	nd	nd	nd
Heptachlor epoxide	nd	nd	nd	nd
Mirex	nd	0.28	nd	nd
Trans-Nonachlor	1.25	2.02	1.58	1.08
2,4'-DDE	384.07	921.50	679.93	446.31
4,4'-DDE	3361.82	7544.87	5160.91	4600.97
2,4'-DDD	0.00	171.05	110.66	97.09
4,4'-DDD	370.35	807.84	580.27	391.30
2,4'-DDT	8.81	6.46	12.10	19.33
4,4'-DDT	178.93	213.54	149.43	305.07
Total Pesticides	4307.33	9670.36	6703.66	5863.83
Total DDTs	4303.98	9665.26	6693.30	5860.06
%DDTs in Total Pesticides	99.92	99.95	99.85	99.94
2,4'-DDT/4,4'-DDT	0.05	0.03	0.08	0.06
<u>2,4'- and 4,4'-DDE</u>	19.95	38.48	36.16	15.56
<u>2,4'- and 4,4'-DDT</u>				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13d. Pesticides in NOAA IV. (ng/g)

Pb-210 Date	1950	1939	1928	1917
Compound	8-9cm	9-10cm	10-11cm	11-12cm
Aldrin	0.38	nd	0.11	nd
Alpha-Chlordane	1.32	1.44	2.42	0.78
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	nd	0.20	0.41	0.22
Lindane (gamma-BHC)	0.63	0.09†	0.11†	0.13†
Heptachlor	nd	nd	nd	nd
Heptachlor epoxide	nd	nd	nd	nd
Mirex	0.31	nd	nd	nd
Trans-Nonachlor	1.03	1.43	2.20	0.66
2,4'-DDE	323.00	184.53	239.58	98.37
4,4'-DDE	3089.12	1665.35	1763.84	1754.41
2,4'-DDD	81.16	27.88	32.91	22.06
4,4'-DDD	251.33	177.91	183.63	87.43
2,4'-DDT	18.98	16.15	9.72	13.84
4,4'-DDT	147.83	246.67	153.33	90.02
Total Pesticides	3915.10	2321.65	2388.26	2067.92
Total DDTs	3911.43	2318.49	2383.01	2066.12
%DDTs in Total Pesticides	99.91	99.86	99.78	99.91
2,4'-DDT/4,4'-DDT	0.13	0.07	0.06	0.15
<u>2,4'- and 4,4'-DDE</u>	20.46	7.04	12.29	17.84
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13d. Pesticides in NOAA IV. (ng/g)

Pb-210 Date	1899
Compound	12-14 cm
Aldrin	nd
Alpha-Chlordane	0.14
Dieldrin	nd
Endrin	nd
Hexachlorobenzene	0.10
Lindane (gamma-BHC)	nd
Heptachlor	nd
Heptachlor epoxide	nd
Mirex	0.04 †
Trans-Nonachlor	0.10
2,4'-DDE	45.05
4,4'-DDE	273.72
2,4'-DDD	5.47
4,4'-DDD	31.01
2,4'-DDT	0.38
4,4'-DDT	11.52
Total Pesticides	367.51
Total DDTs	367.14
%DDTs in Total Pesticides	99.90
2,4'-DDT/4,4'-DDT	0.03
<u>2,4'- and 4,4'-DDE</u>	26.80
2,4'- and 4,4'-DDT	

nd: not detected; below MDL

† Between MDL and LOQ

Table 13e. Pesticides in NOAA V. (ng/g)

Pb-210 Date	1989-81	1985	1981	1974-77
Compound	0-1cm	1-1.5cm	1.5-2cm	2-3cm
Aldrin	0.85	0.22 †	nd	0.33 †
Alpha-Chlordane	0.60	0.65	0.99	nd
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	1.12	0.25 †	0.48	0.40
Lindane (gamma-BHC)	0.78	0.24 †	0.50 †	1.37
Heptachlor	0.49	nd	nd	nd
Heptachlor epoxide	nd	nd	nd	nd
Mirex	0.44	0.27 †	0.37 †	nd
Trans-Nonachlor	0.75	0.81	1.30	nd
2,4'-DDE	11.21	32.86	72.05	217.29
4,4'-DDE	199.40	252.58	546.29	2192.04
2,4'-DDD	3.61	4.92	10.36	46.09
4,4'-DDD	25.69	22.76	41.57	160.51
2,4'-DDT	5.31	1.28	3.58	16.05
4,4'-DDT	23.27	10.40	43.70	83.69
Total Pesticides	273.51	327.22	721.19	2717.77
Total DDTs	268.48	324.79	717.56	2715.67
%DDTs in Total Pesticides	98.16	99.26	99.50	99.92
2,4'-DDT/4,4'-DDT	0.23	0.12	0.08	0.19
<u>2,4'- and 4,4'-DDE</u>	7.37	24.45	13.08	24.16
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13e. Pesticides in NOAA V (ng/g)

Pb-210 Date	1970	1960	1942	1923
Compound	3-3.5cm	4-5cm	5-6cm	6-7cm
Aldrin	0.54	10.81	nd	0.53
Alpha-Chlordane	0.45	nd	nd	0.32
Dieldrin	7.68	nd	nd	nd
Endrin	nd	2.65	1.80	nd
Hexachlorobenzene	2.26	14.02	37.59	0.48
Lindane (gamma-BHC)	nd	8.86	nd	0.26 †
Heptachlor	nd	nd	nd	nd
Heptachlor epoxide	0.75	nd	0.96	nd
Mirex	nd	nd	4.68	0.19 †
Trans-Nonachlor	nd	nd	nd	nd
2,4'-DDE	624.31	669.12	374.86	46.68
4,4'-DDE	2343.27	2487.15	862.31	171.37
2,4'-DDD	188.01	495.33	402.26	30.25
4,4'-DDD	835.23	1948.21	1189.04	110.50
2,4'-DDT	895.75	1455.81	2638.08	12.26
4,4'-DDT	4944.49	6708.86	6768.46	86.85
Total Pesticides	9842.74	13800.82	12280.03	459.70
Total DDTs	9831.06	13764.48	12235.01	457.92
%DDTs in Total Pesticides	99.88	99.74	99.63	99.61
2,4'-DDT/4,4'-DDT	0.18	0.22	0.39	0.14
<u>2,4'- and 4,4'-DDE</u>	0.51	0.39	0.13	2.20
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13e. Pesticides in NOAA V (ng/g)

Pb-210 Date	1902
Compound	7-8cm
Aldrin	nd
Alpha-Chlordane	0.13 †
Dieldrin	nd
Endrin	nd
Hexachlorobenzene	0.24
Lindane (gamma-BHC)	0.20 †
Heptachlor	nd
Heptachlor epoxide	0.19
Mirex	0.12 †
Trans-Nonachlor	nd
2,4'-DDE	4.67
4,4'-DDE	26.61
2,4'-DDD	4.41
4,4'-DDD	14.96
2,4'-DDT	0.81
4,4'-DDT	4.39
Total Pesticides	56.73
Total DDTs	55.85
%DDTs in Total Pesticides	98.45
2,4'-DDT/4,4'-DDT	0.19
<u>2,4'- and 4,4'-DDE</u>	6.02
2,4'- and 4,4'-DDT	

nd: not detected; below MDL

† Between MDL and LOQ

Table 13f. Pesticides in NOAA VI (ng/g)

Pb-210 Date	1987	1984	1980	1978
Compound	0-0.5cm	0.5-1cm	1-1.5cm	1.5-2cm
Aldrin	0.67	nd	0.82	nd
Alpha-Chlordane	0.28	0.46	0.37	0.39
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	0.44	0.73	0.47	0.62
Lindane (gamma-BHC)	0.05†	0.10†	0.39	0.18†
Heptachlor	0.25	nd	0.05	nd
Heptachlor epoxide	nd	nd	nd	nd
Mirex	nd	nd	nd	nd
Trans-Nonachlor	0.33†	0.52	0.50	0.51
2,4'-DDE	9.88	12.84	30.63	70.02
4,4'-DDE	152.36	155.23	272.31	411.50
2,4'-DDD	2.81	2.84	14.20	11.59
4,4'-DDD	14.07	11.36	44.69	46.70
2,4'-DDT	3.67	2.31	429.73	4.13
4,4'-DDT	23.25	6.84	634.73	26.31
Total Pesticides	208.06	193.22	1428.92	571.95
Total DDTs	206.05	191.41	1426.31	570.26
%DDTs in Total Pesticides	99.03	99.07	99.82	99.70
2,4'-DDT/4,4'-DDT	0.16	0.34	0.68	0.16
<u>2,4'- and 4,4'-DDE</u>	6.03	18.37	0.28	15.82
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13f. Pesticides in NOAA VI (ng/g)

Pb-210 Date	1975	1961	1946	1930
Compound	2-2.5cm	2.5-3cm	3-3.5cm	3.5-4cm
Aldrin	0.64	0.87	1.23	nd
Alpha-Chlordane	0.30	0.46	0.57	0.46
Dieldrin	nd	nd	nd	nd
Endrin	nd	nd	nd	nd
Hexachlorobenzene	0.25	1.87	1.95	0.52
Lindane (gamma-BHC)	0.28	nd	0.28	0.67
Heptachlor	nd	0.35†	nd	nd
Heptachlor epoxide	nd	nd	nd	nd
Mirex	0.15†	nd	nd	nd
Trans-Nonachlor	0.25†	0.30†	0.48	0.38
2,4'-DDE	45.70	34.26	44.93	46.51
4,4'-DDE	450.94	211.92	332.40	333.34
2,4'-DDD	13.22	14.99	25.73	13.33
4,4'-DDD	40.54	43.55	71.64	33.31
2,4'-DDT	11.31	21.95	44.91	4.70
4,4'-DDT	49.09	63.62	82.41	14.20
Total Pesticides	612.66	394.15	606.54	447.42
Total DDTs	610.80	390.29	602.02	445.39
%DDTs in Total Pesticides	99.70	99.02	99.25	99.55
2,4'-DDT/4,4'-DDT	0.23	0.35	0.54	0.33
<u>2,4'- and 4,4'-DDE</u>	8.22	2.88	2.96	20.10
2,4'- and 4,4'-DDT				

nd: not detected; below MDL

† Between MDL and LOQ

Table 13f. Pesticides in NOAA VI (ng/g)

Pb-210 Date	1905	1889
Compound	4-5cm	5-6cm
Aldrin	0.56	0.15 †
Alpha-Chlordane	0.40	0.11 †
Dieldrin	nd	nd
Endrin	nd	nd
Hexachlorobenzene	0.53	0.12 †
Lindane (gamma-BHC)	nd	nd
Heptachlor	nd	nd
Heptachlor epoxide	nd	0.16 †
Mirex	nd	nd
Trans-Nonachlor	0.18 †	nd
2,4'-DDE	49.11	32.51
4,4'-DDE	262.31	88.92
2,4'-DDD	16.52	10.93
4,4'-DDD	71.95	43.86
2,4'-DDT	8.62	3.62
4,4'-DDT	92.22	21.06
Total Pesticides	502.40	201.45
Total DDTs	500.73	200.90
%DDTs in Total Pesticides	99.67	99.73
2,4'-DDT/4,4'-DDT	0.09	0.17
<u>2,4'- and 4,4'-DDE</u>	3.09	4.92
<u>2,4'- and 4,4'-DDT</u>		

nd: not detected; below MDL

† Between MDL and LOQ

Table 14. 2,4'-DDT/4,4'-DDT ratios of selected sediment sections

Station section	Pb-210 Age	2,4'-DDT/4,4'-DDT
II 2-2.5cm	1966*	0.32
2.5-3cm	1959*	0.56
III 3-4cm	1965*	0.55
4-5cm	1956*	0.47
5-6cm	1948*	0.28
V 3-3.5cm	1970	0.18
4-5cm	1960	0.22
5-6cm	1942	0.39
VI 1-1.5cm	1980	0.68

* 5-8 yrs time offset probable. See text for details.

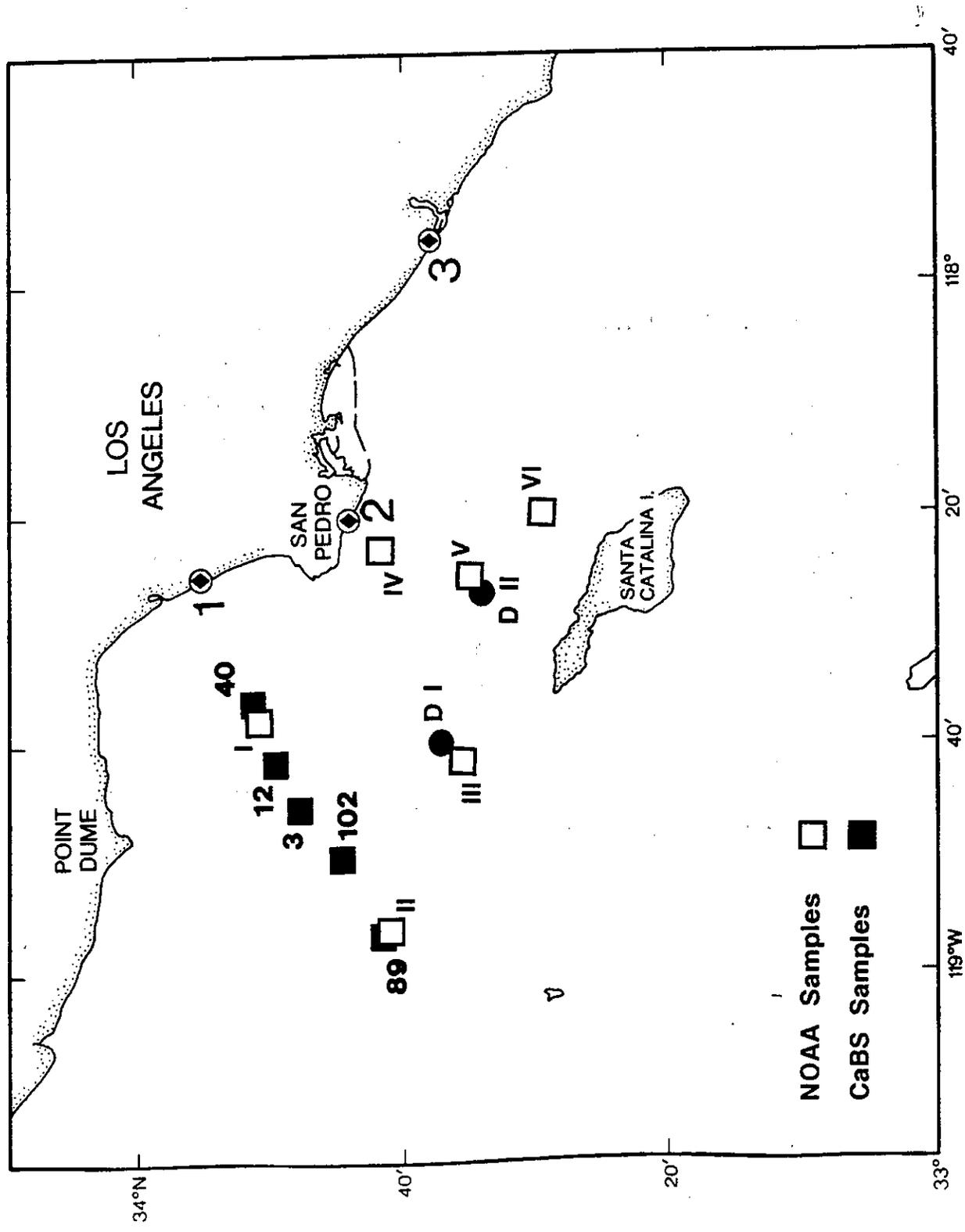


Figure 1. Station locations of NOAA NS&T project in SM/SP basins (□). Also indicated are station locations from CaBS project (■) and dumpsites DI and DII(●), 1, 2 and 3 are the Los Angeles City (Hyperion), County (JWPCP) and Orange County Sanitation Districts.

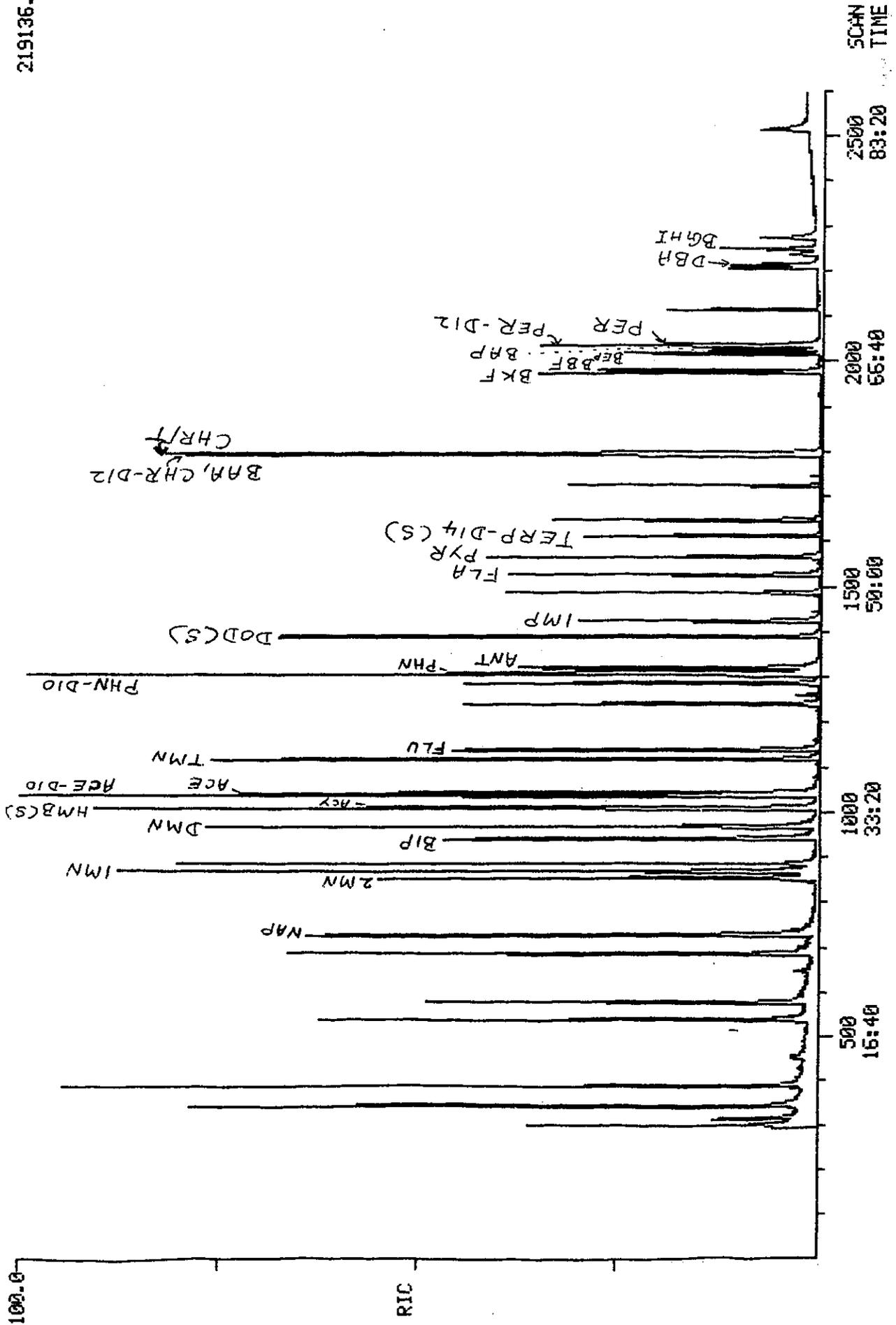


Figure 2. Mass chromatogram (RIC) of standard PAH mixture (10 ng/ul of each target analyte). See Table 1 for explanation for abbreviations of compound names. Only target analytes are labelled.

2899760.

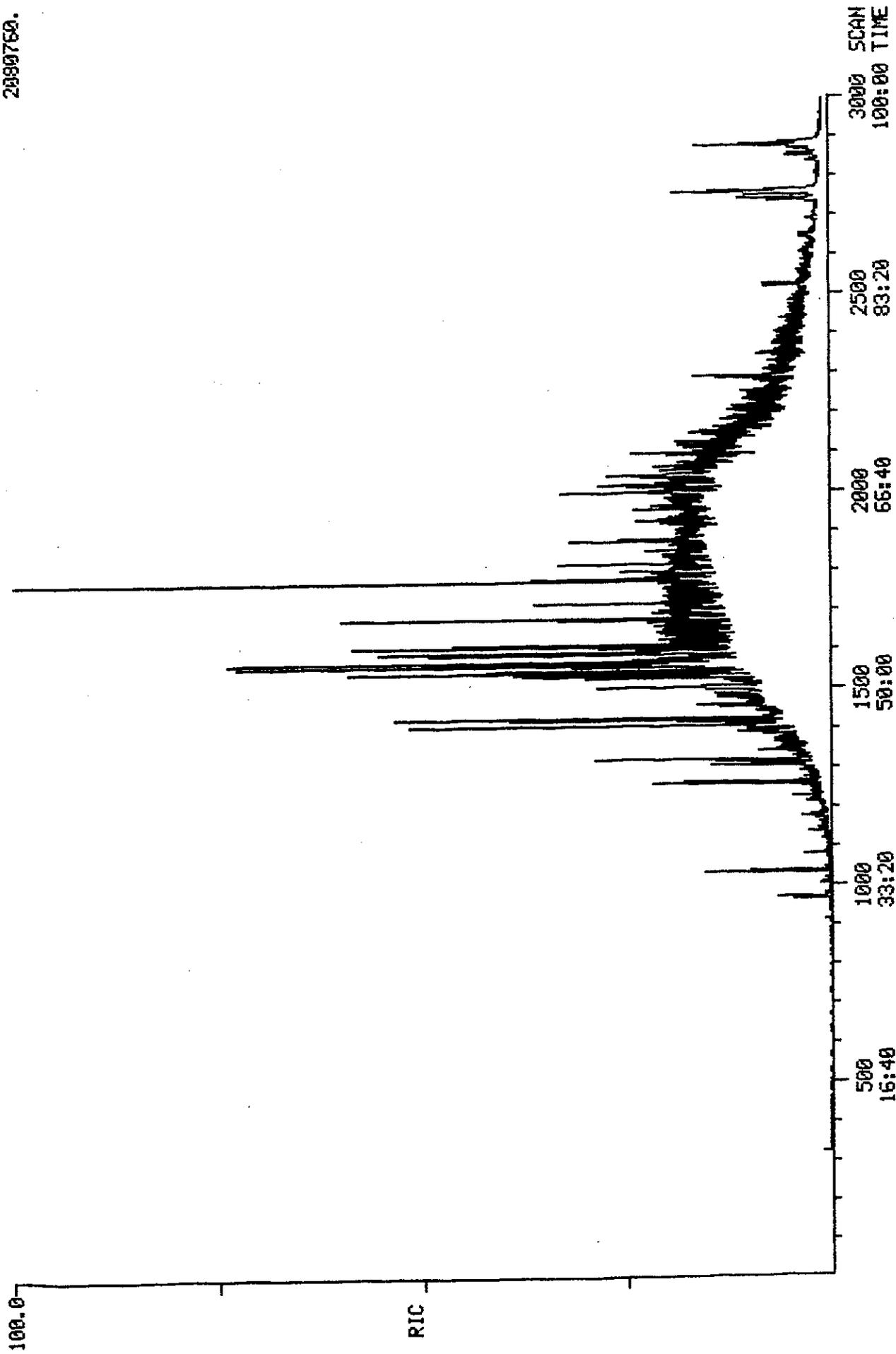


Figure 3. Mass chromatogram (RIC) of sample: NOAA I, 5-6cm.

Figure 4a(i). GC/ECD of standard mixture of chlorinated pesticides and PCBs (100 pg/ul of each compound).

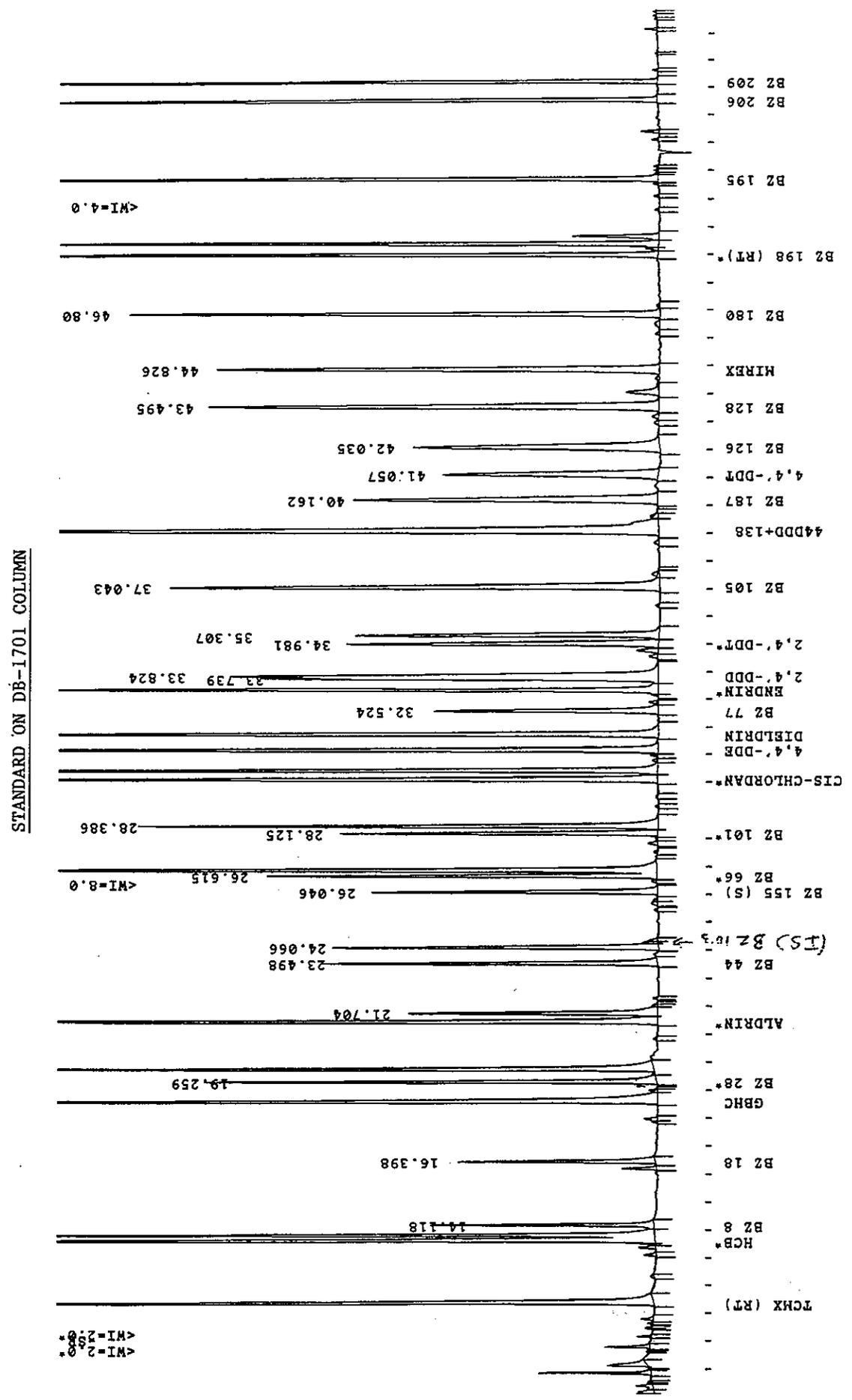


Figure 4a(ii). GC/ECD: System blank

DB-1701 COLUMN

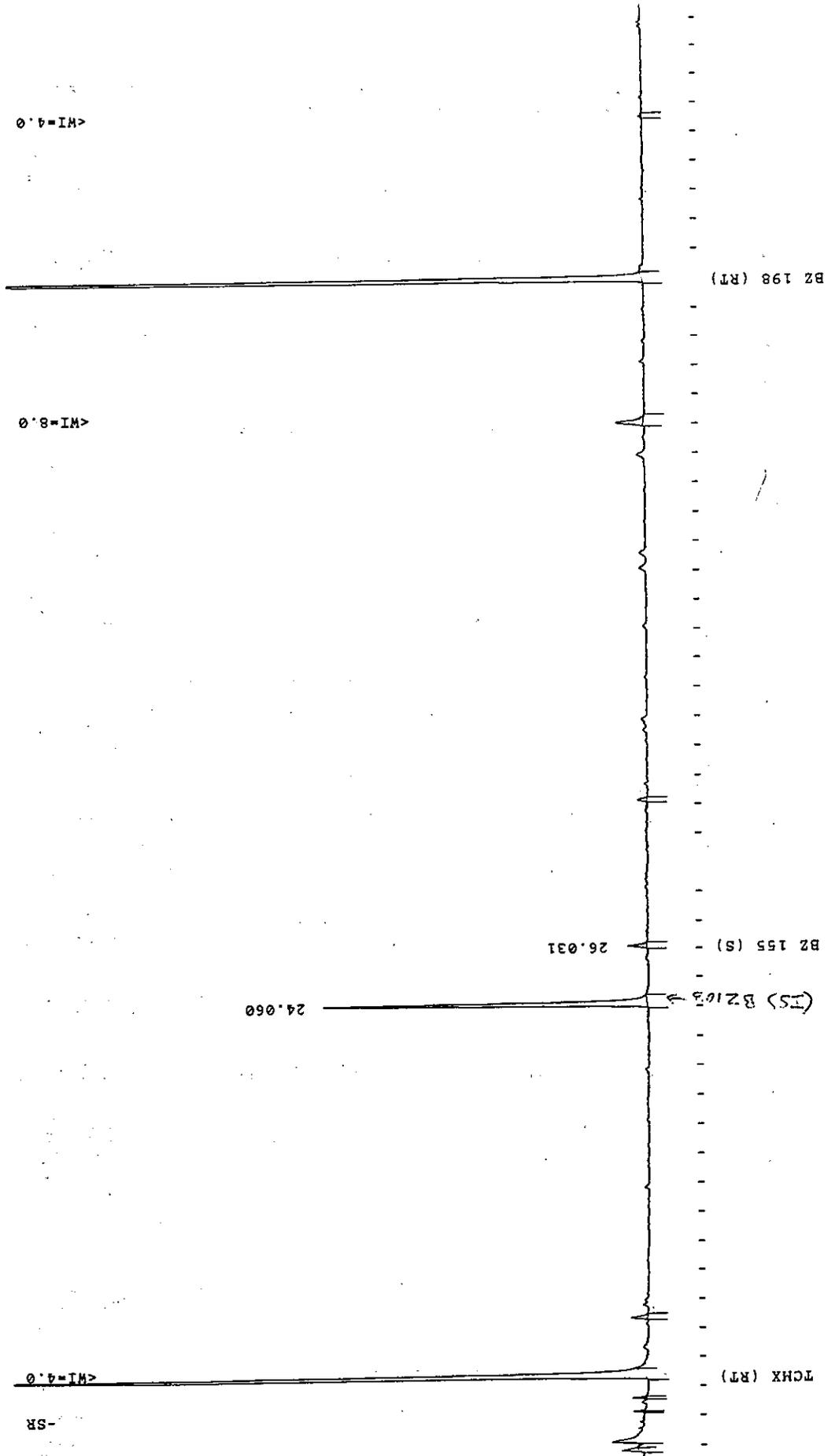


Figure 4b(i). GC/ECD of standard mixture of chlorinated pesticides and PCBs (100 pg/ul of each compound).

STANDARD ON DB-5 COLUMN

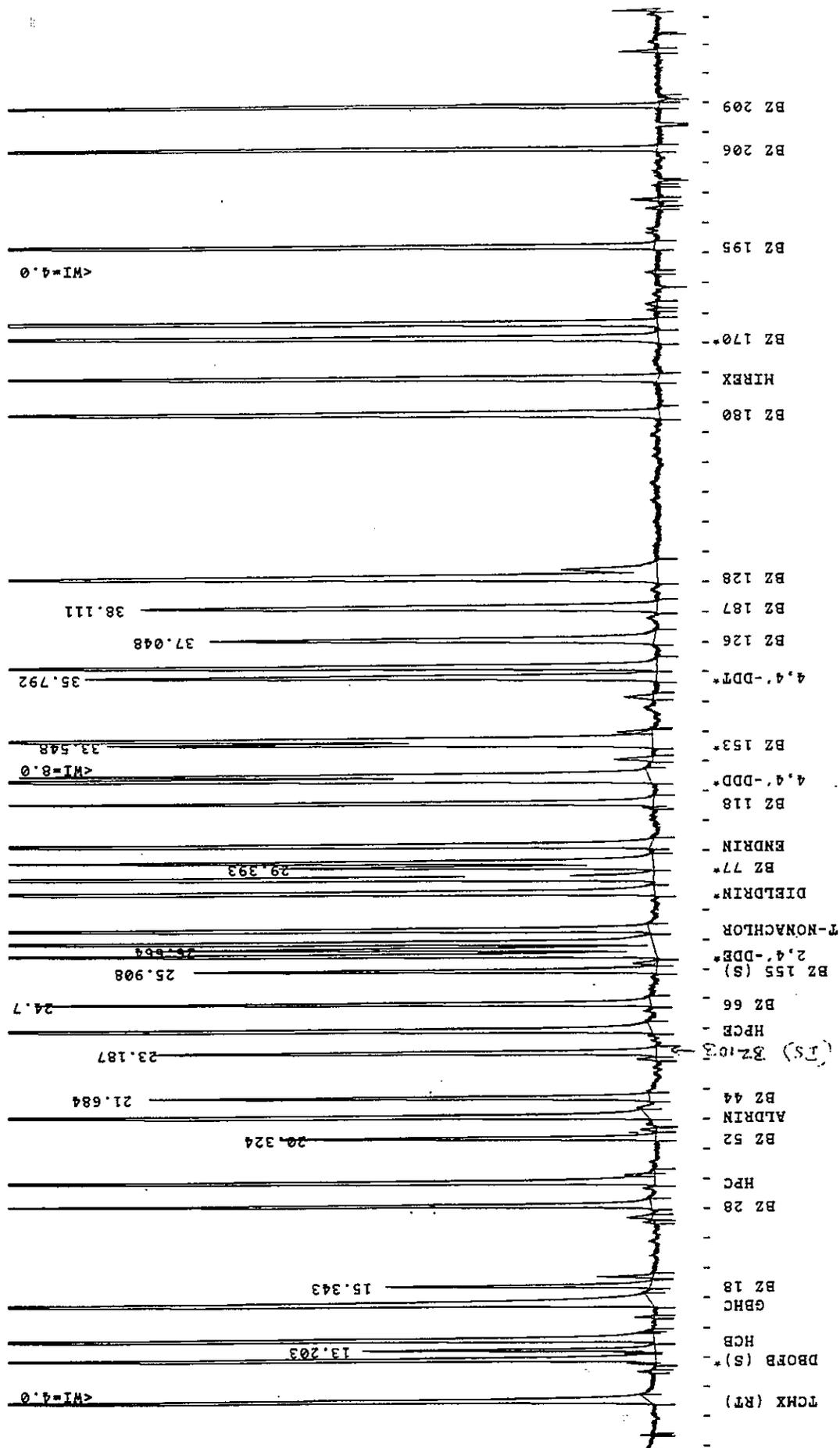


Figure 4b(ii). GC/ECD: System blank

DB-5 COLUMN

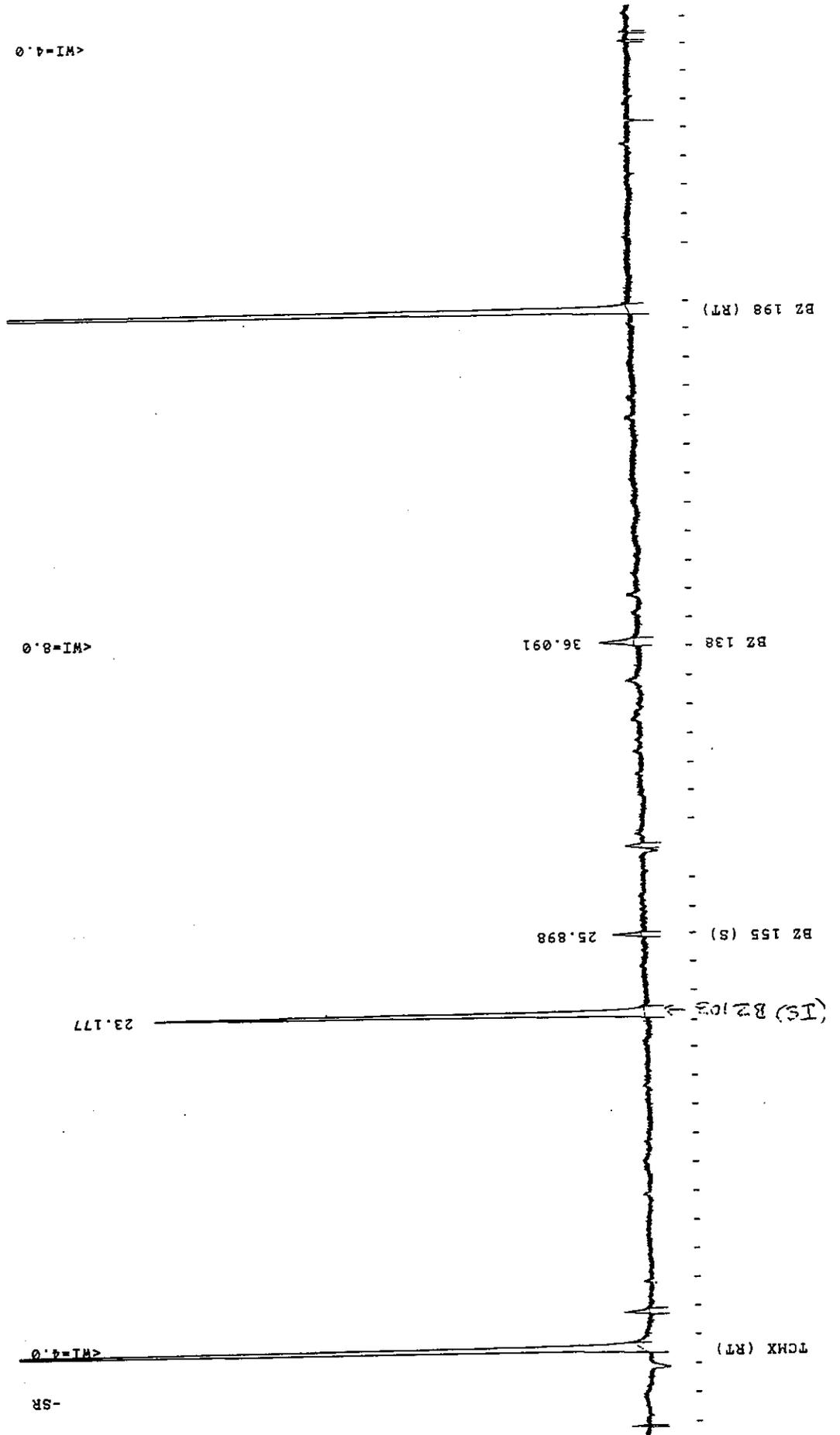


Figure 5a(f) GC/ECD of sample NOAA V, 0-lcm.

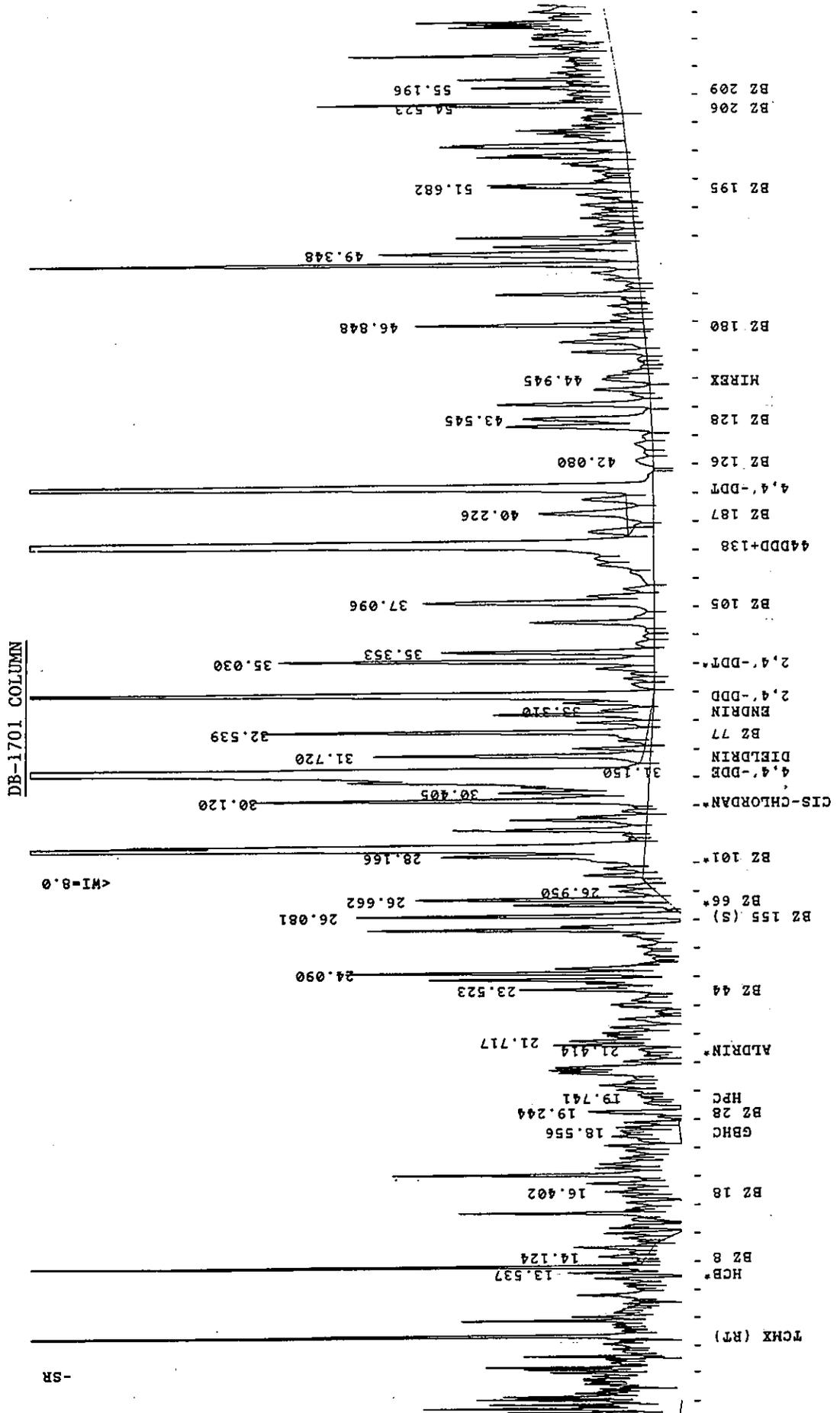


Figure 5a (ii). GC/ECD of procedure blank. Note that procedure blank was run only in 100 ul while all the samples were run after diluting the original volume (200 ul) several folds. The blank run here, therefore, is concentrated at least 2x compared to sample runs.

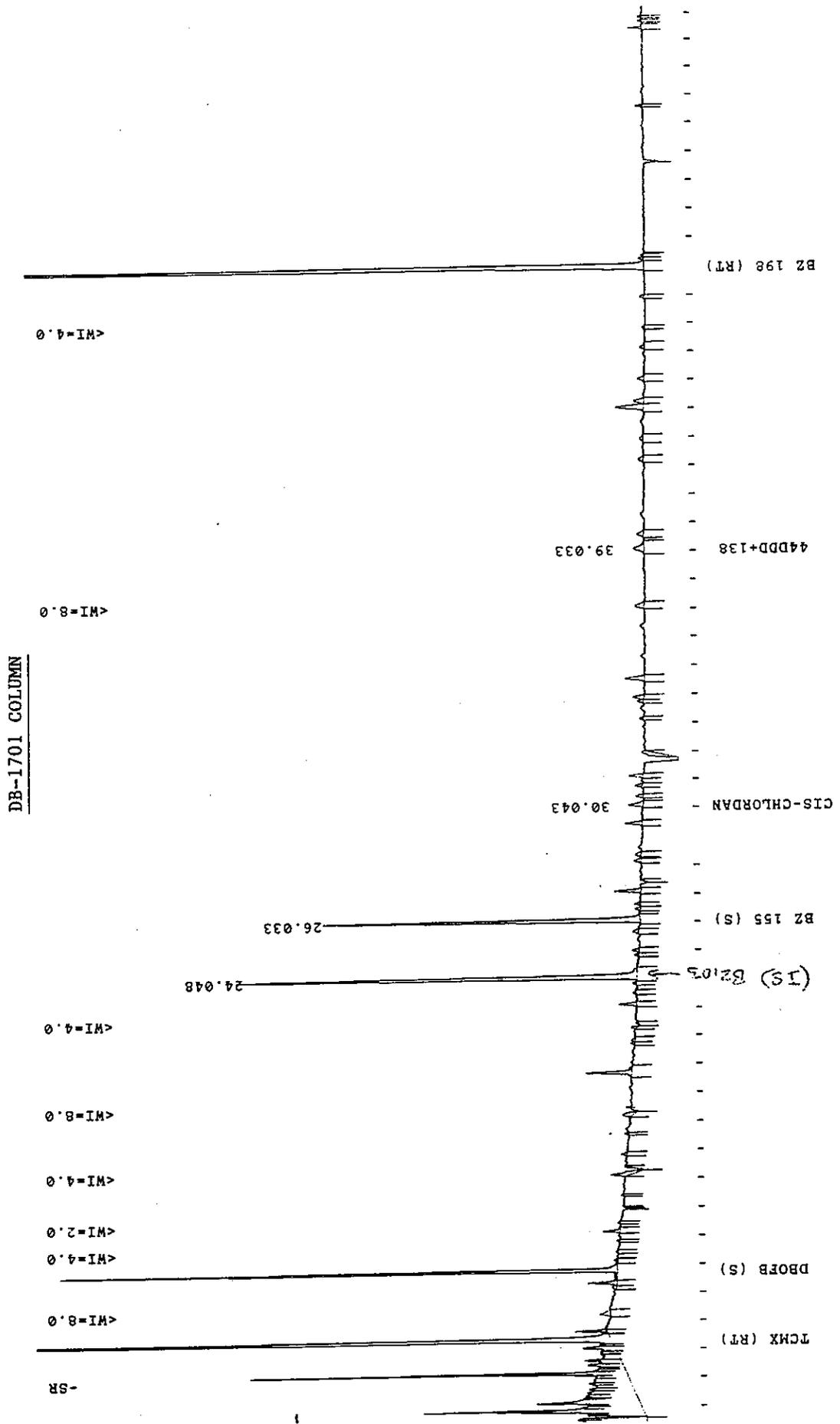


Figure 5b(i). GC/ECD of sample NOAA V, 0-1cm.

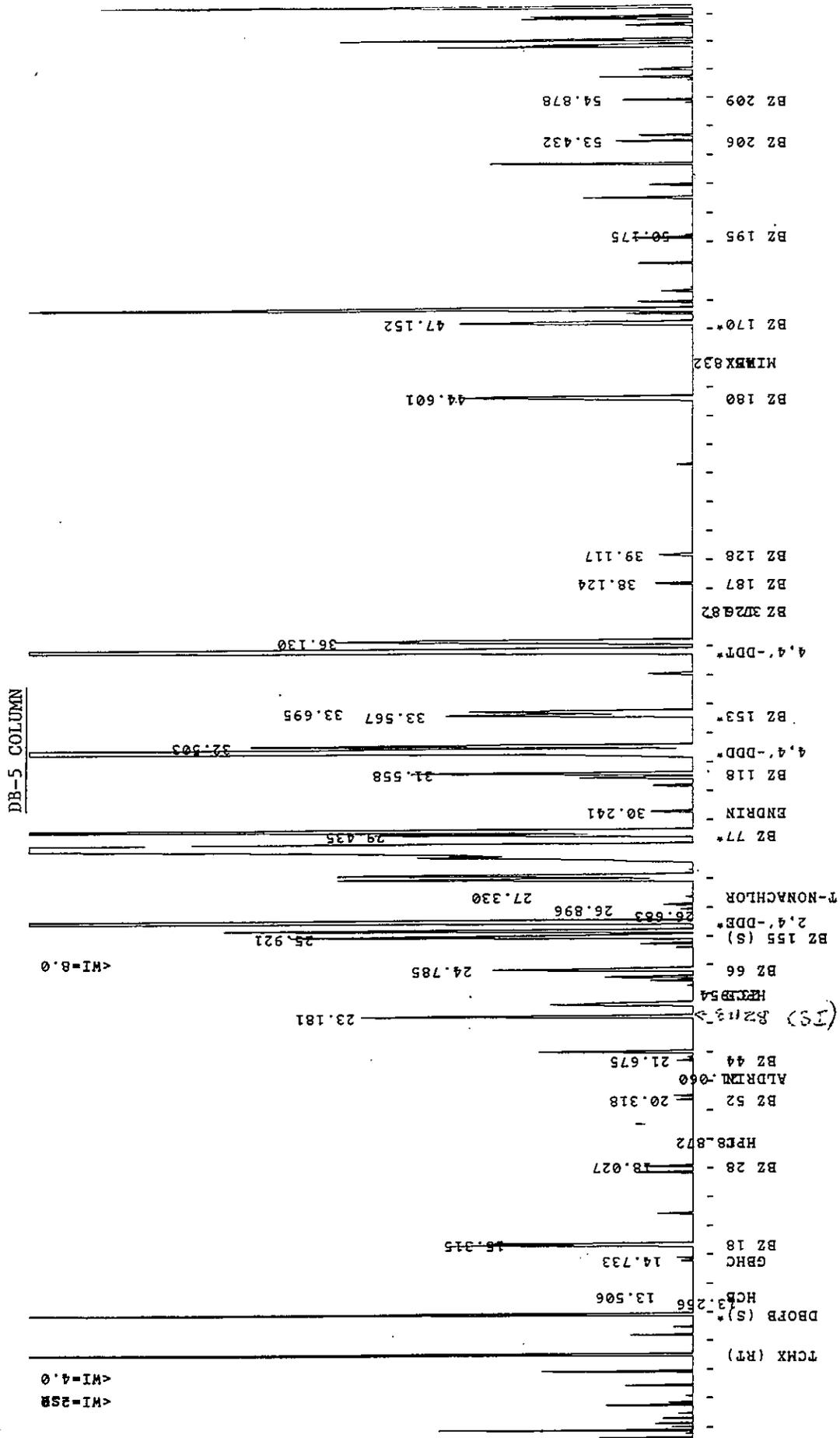


Figure 5b (ii). GC/ECD of procedure blank. Note that procedure blank was run only in 100 ul while all the samples were run after diluting the original volume (200 ul) several folds. The blank run here, therefore, is concentrated at least 2x compared to sample runs.

DB-5 COLUMN

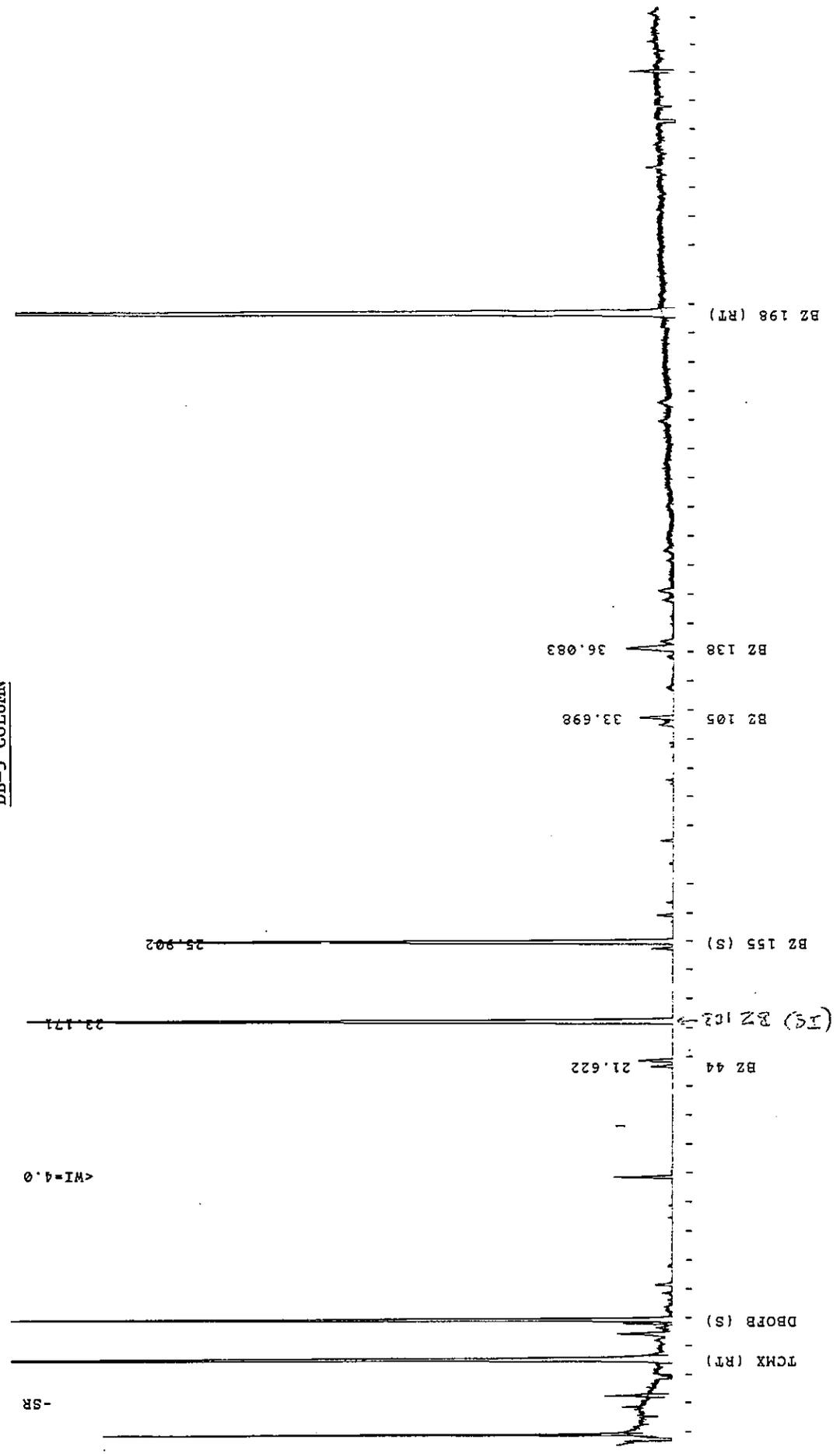


Figure 6. Total organic carbon and nitrogen in the sediment sections.

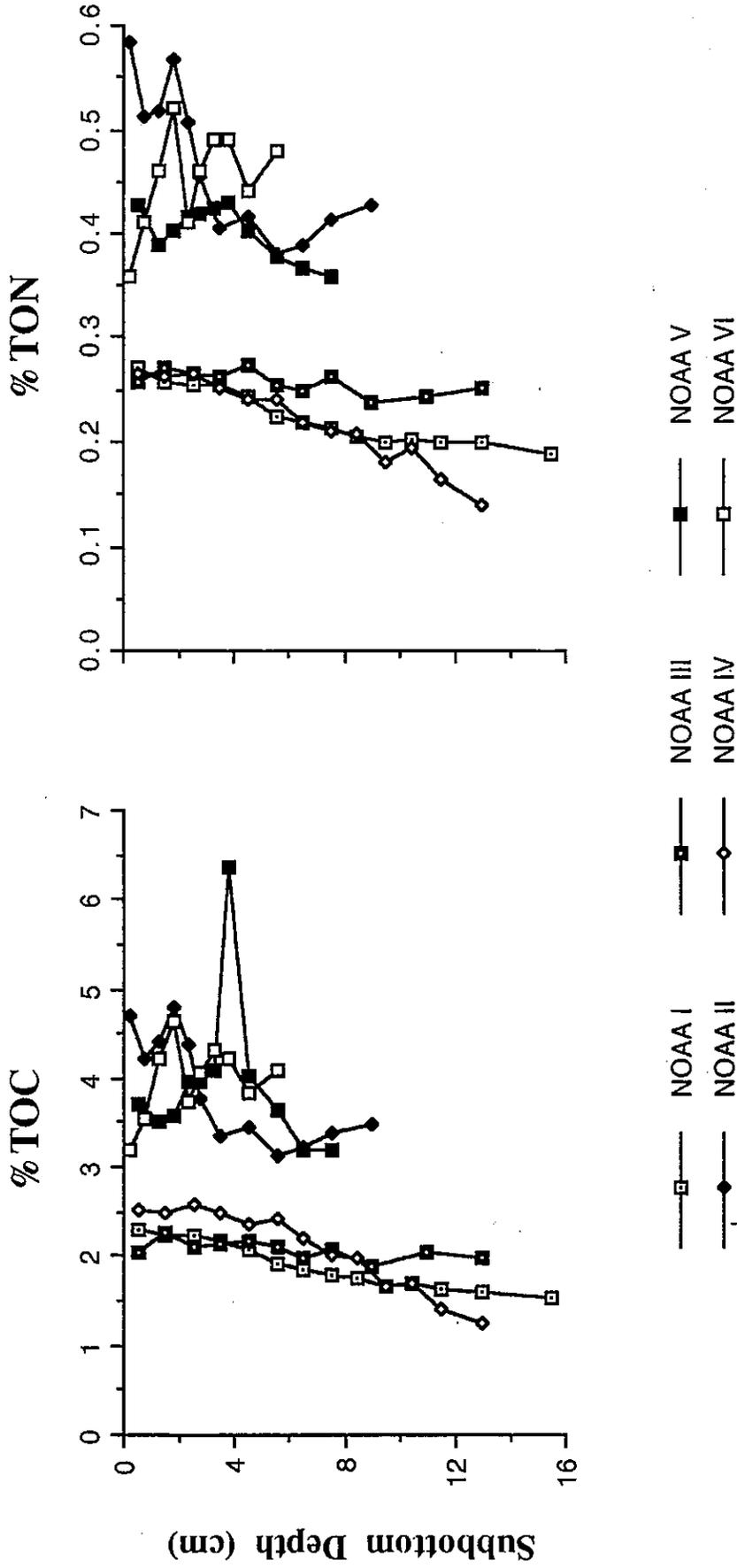
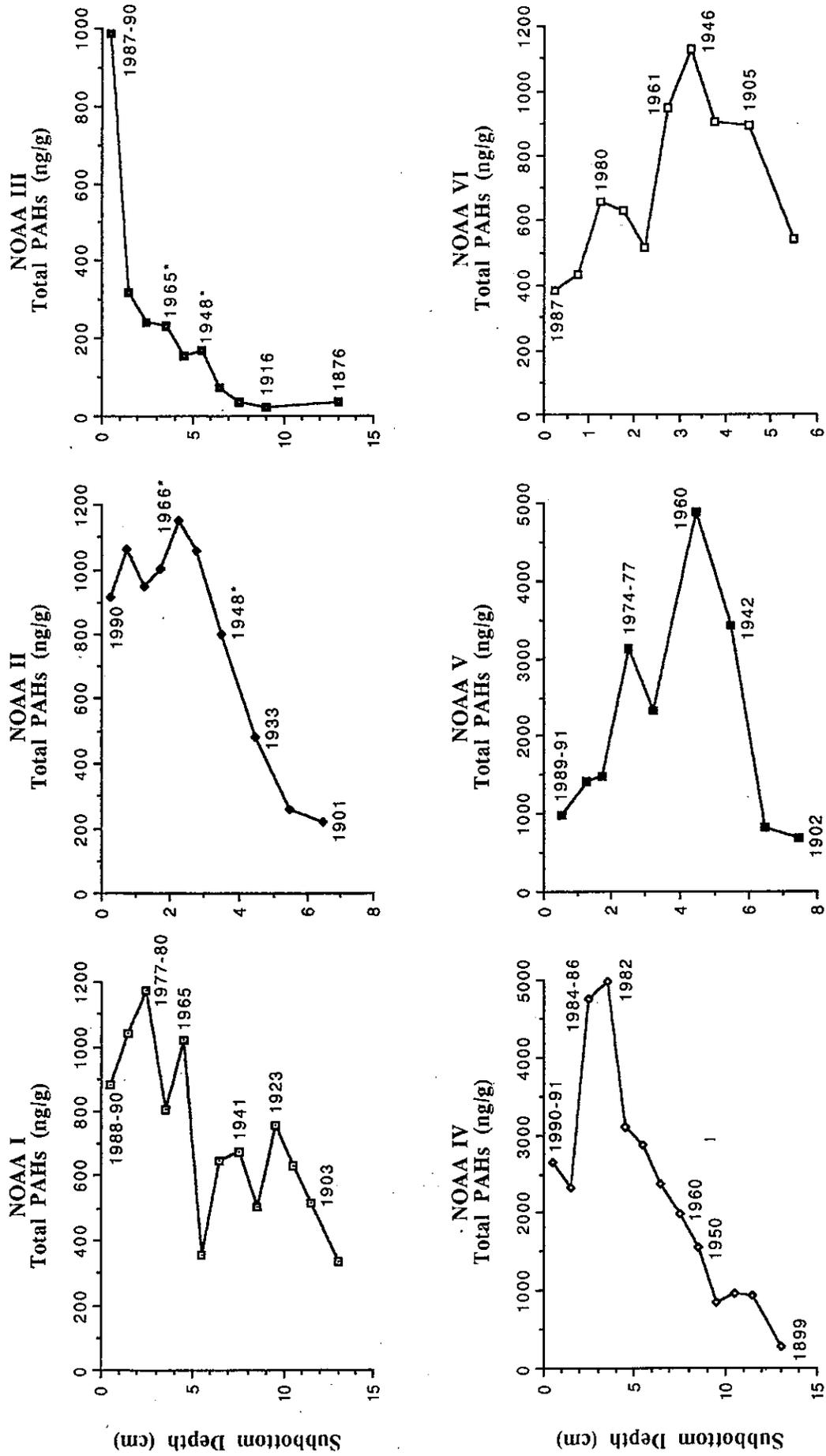


Figure 7. Historic profiles of PAHs in the sediments.



*: Could be 1961-66 and 1943-48 in NOAA II and 1961-65, 1940-48 in NOAA III. See text for details.

Figure 8. Distribution of PAH (total) in CaBS sediments (Venkatesan and Kaplan, 1986).

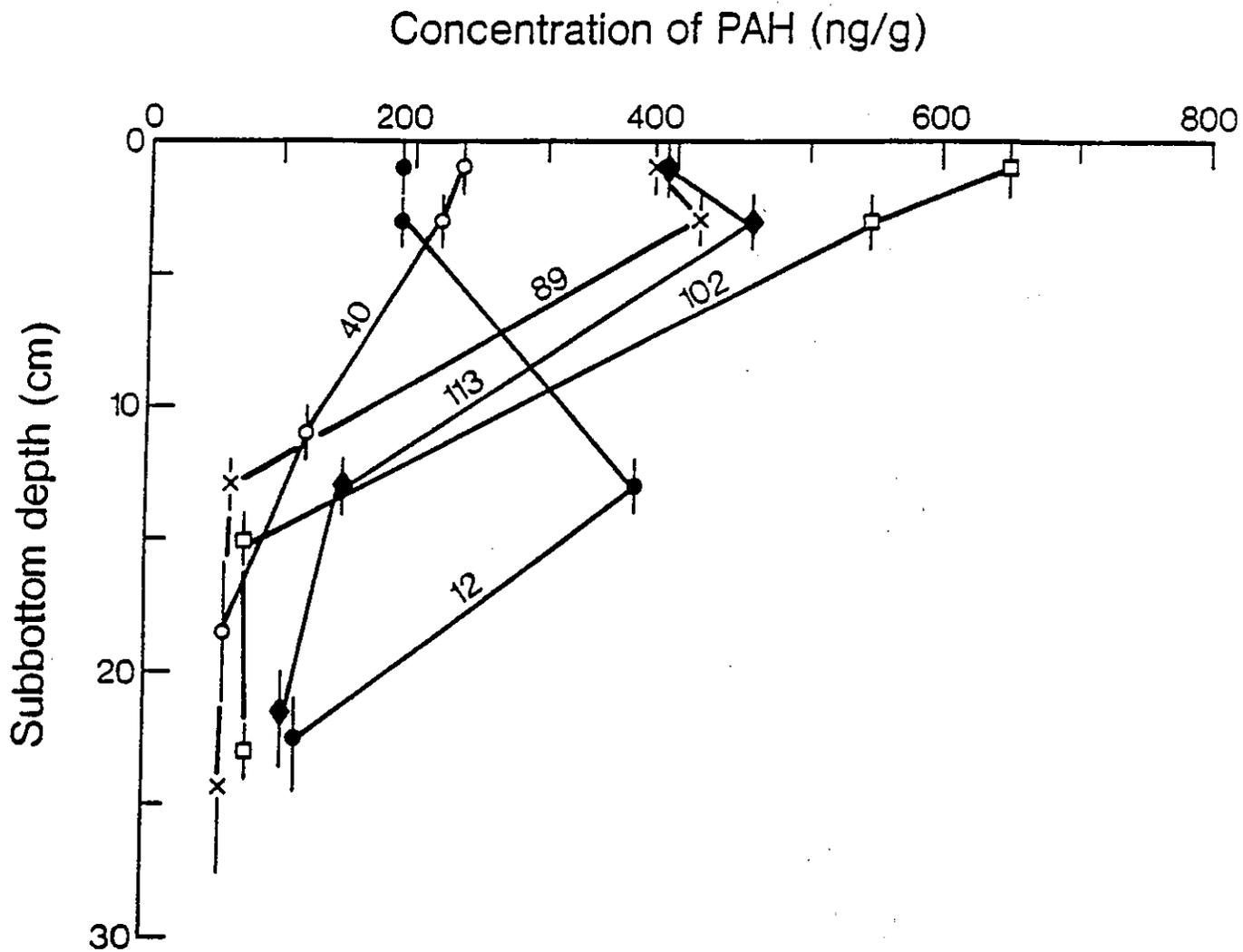


Figure 9. Historic profiles of total and selected PCBs in the sediments.

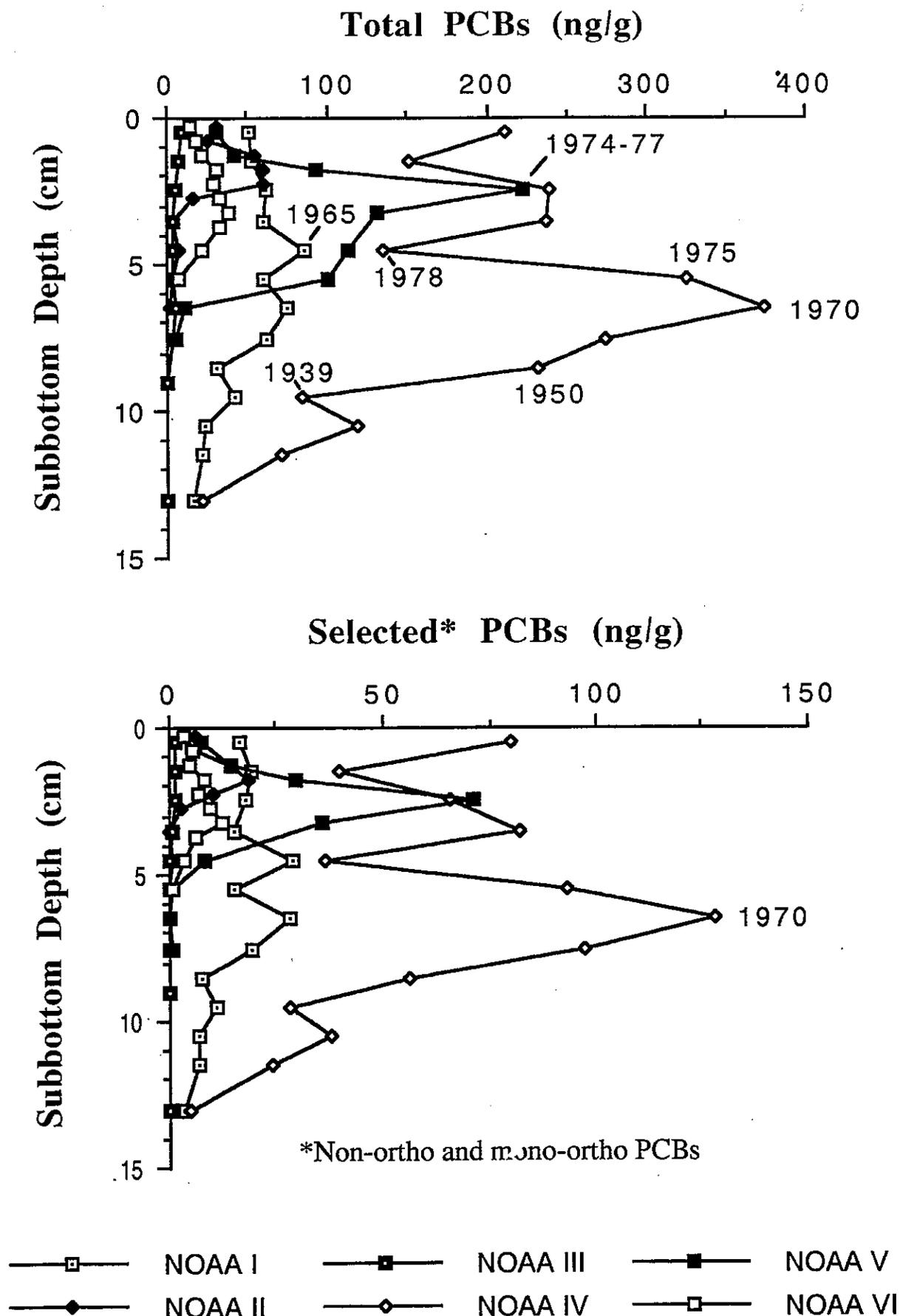


Figure 10. Distribution of PCBs by chlorine atoms in modern and pre-anthropogenic strata in the sediments.

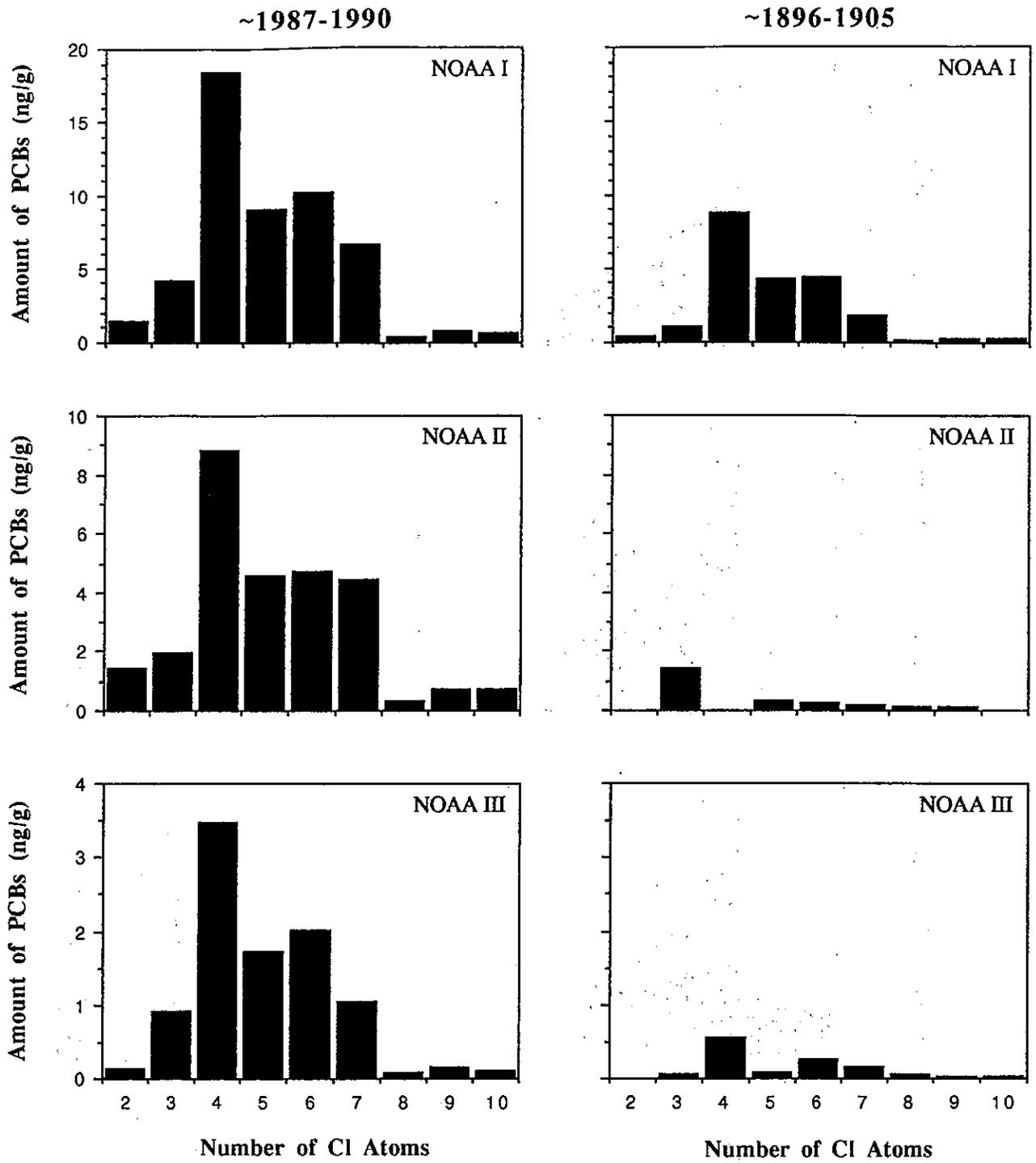


Figure 10. Distribution of PCBs by chlorine atoms in modern and pre-anthropogenic strata in the sediments.

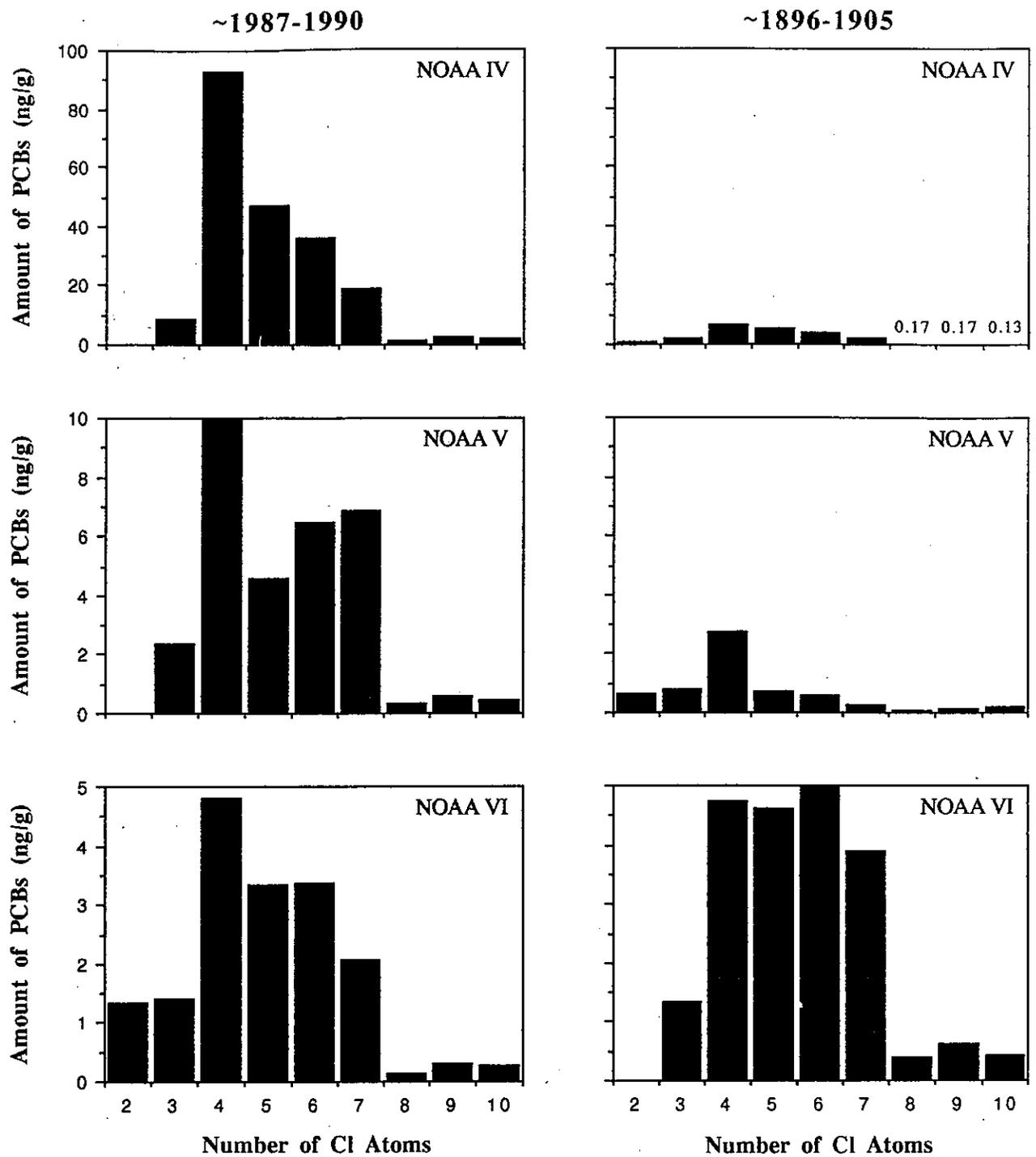


Figure 11. Historic profiles of the distribution of total chlorinated pesticides and DDTs (DDEs + DDDs + DDTs) in the sediments

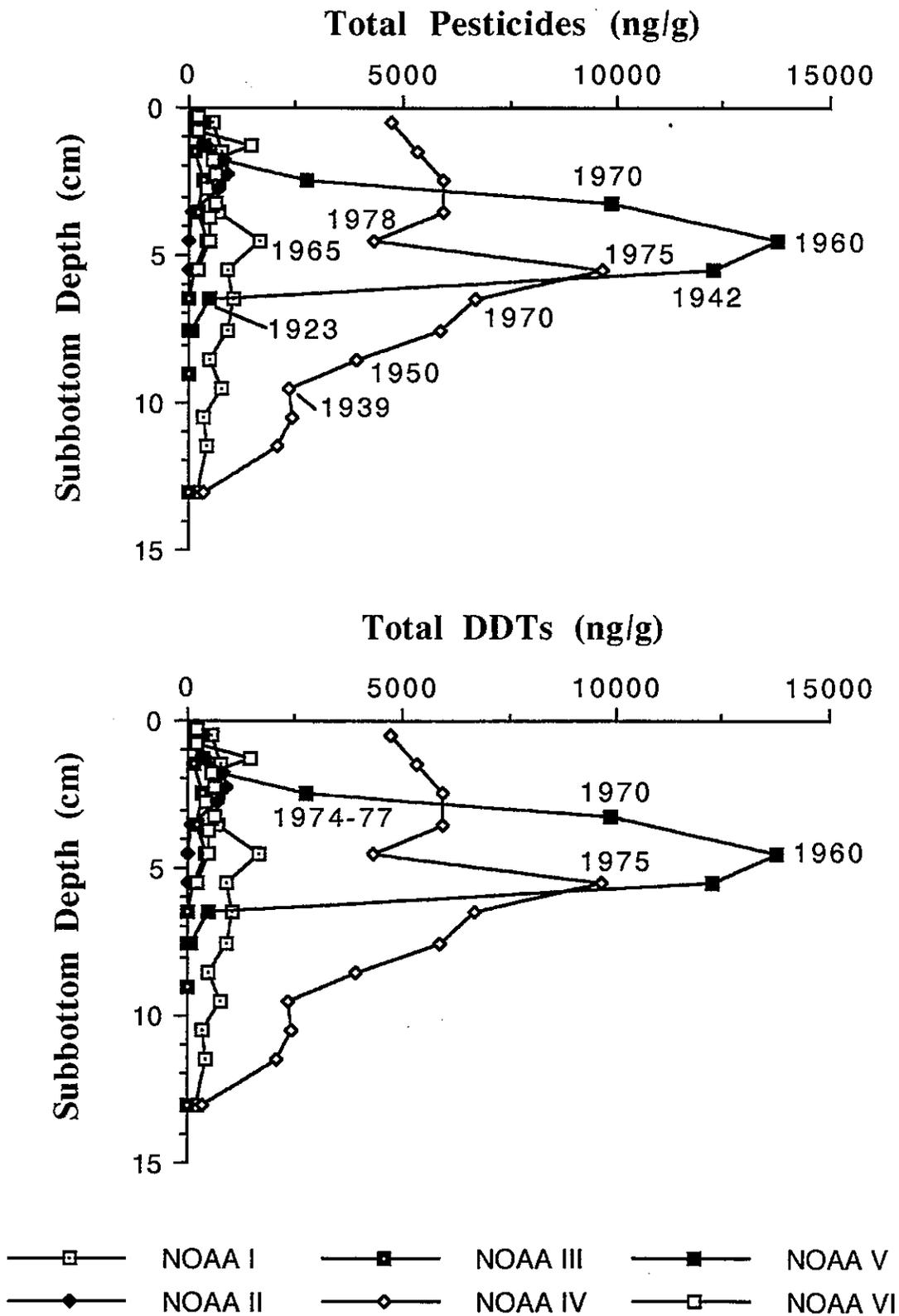


Figure 12. Historic profiles of the distribution of DDTs and their metabolites in the sediments.

*: Could be 1967-72 in NOAA II and 1951-56 in III. See text.

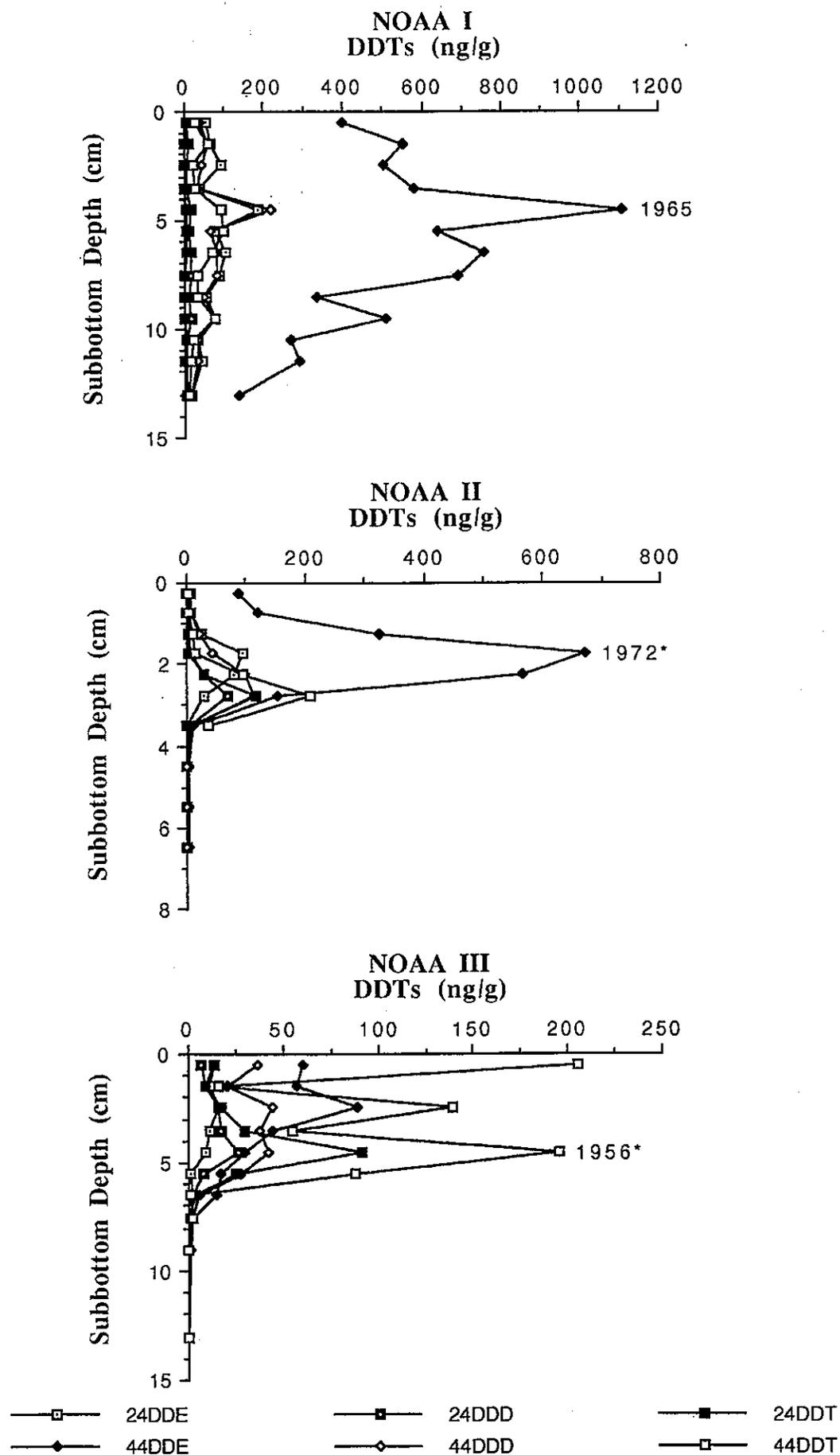


Figure 12. Historic profiles of the distribution of DDTs and their metabolites in the sediments.
 *: Could be 1967-72 in NOAA II and 1951-56 in III. See text.

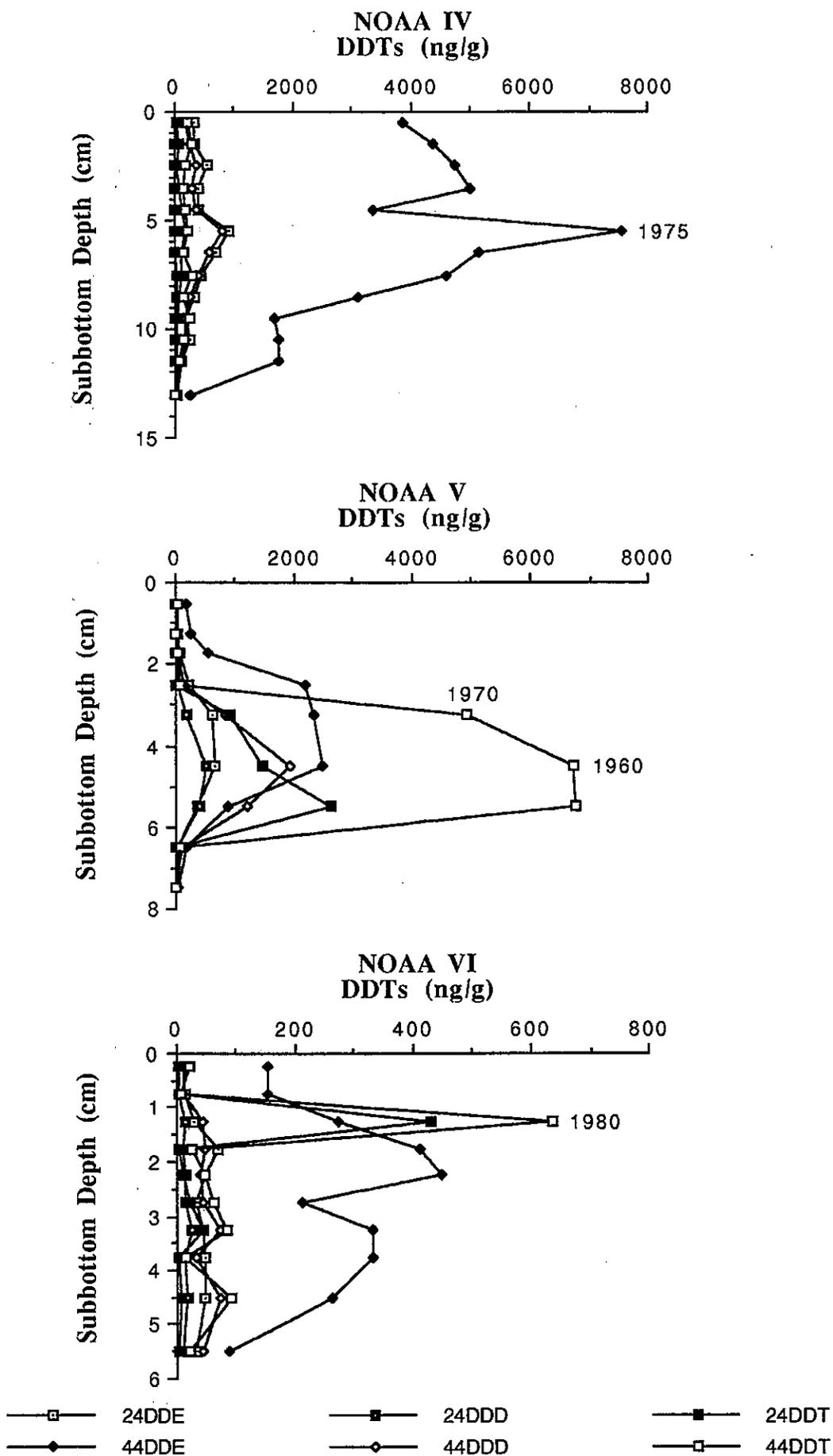
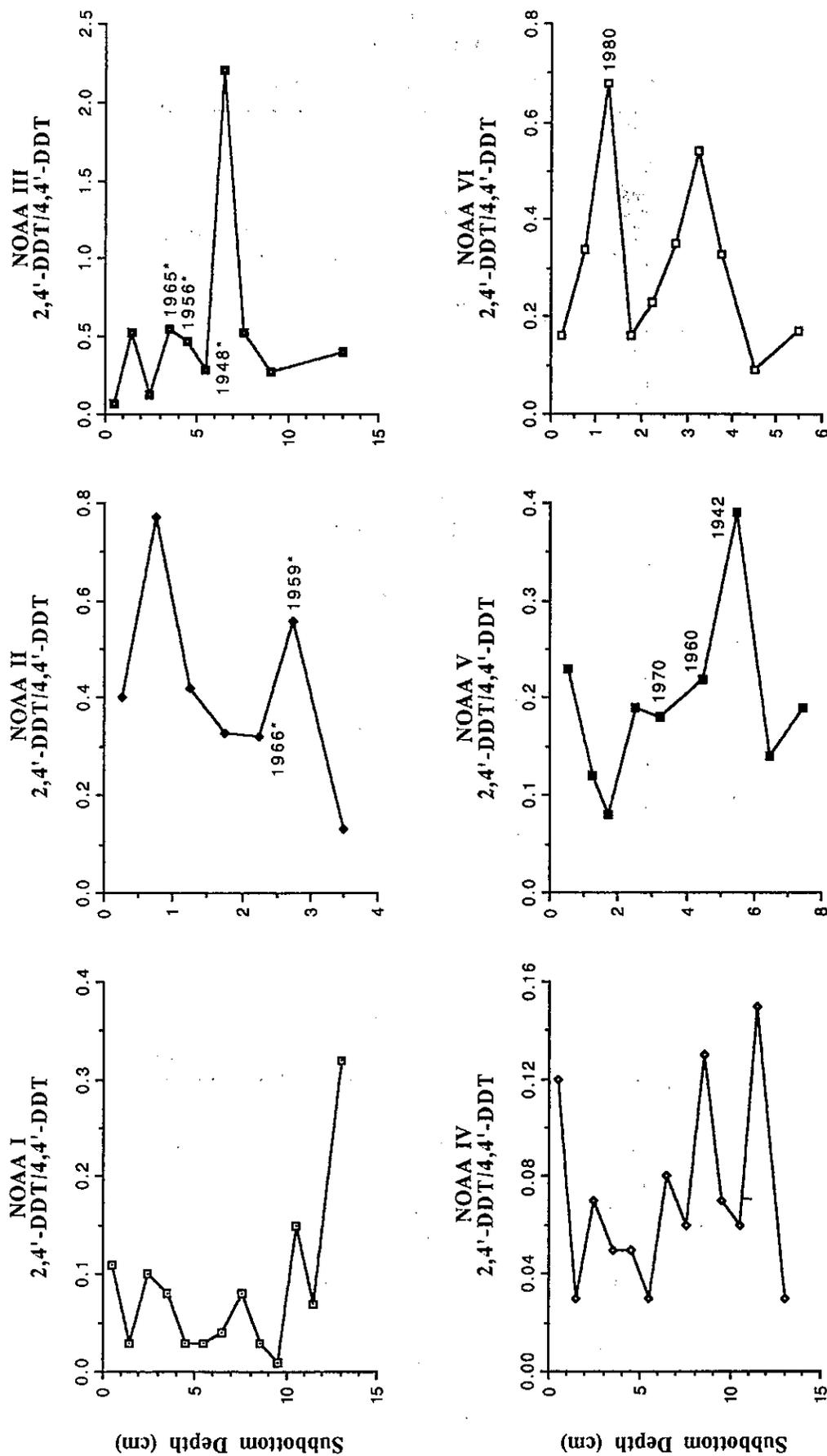


Figure 13. 2,4'-DDT/4,4'-DDT ratios in sediment cores



*: Could be 1961-66 and 1954-59 in NOAA I, and 1960-65, 1951-56 and 1940-48 in NOAA III. See text for details.