

## TALC IN THE SUSPENDED MATTER OF THE NORTHWESTERN ATLANTIC

**Key Words**—Continental Shelf, Pollution, Sediment, Suspended matter, Talc.

### INTRODUCTION

Knowledge of the distribution, concentration, and composition of suspended particulate matter in seawater is important to the understanding of sedimentation processes on the Continental Shelf. Because the surfaces of both organic and inorganic particles have high affinities for pollutants, such as certain trace metals, chlorinated hydrocarbons, and petroleum (Bothner *et al.*, 1981a), suspended matter plays a major role in the transport and fate of pollutants introduced into shelf and coastal waters. Although the composition of bottom sediments on the shelf off the northeastern United States is reasonably well known, the mineralogical composition and distribution of inorganic suspended matter is less well studied.

Two cruises were conducted in 1978 and 1979 by the U.S. Geological Survey to examine the distribution and composition of suspended matter in the waters off the northeastern United States. Talc was detected in suspended matter samples collected during this study from the water column on the Continental Shelf and Upper Slope between Wilmington Canyon and the southern Gulf of Maine. Talc may have been transported to the water column by rivers carrying terrigenous detritus, by eolian means, by artificial deposition, or by resuspension of bottom sediments.

Talc is used in many commercial products including paint, ceramics, rubber, roofing, paper, toiletry preparations, and foundry facings, and as a diluent for and carrier of chlorinated hydrocarbons used in pesticides. Most talc mines are concentrated along the Appalachian Mountains in the eastern part of the United States; however, mining and milling operations are distributed throughout the United States. About  $1.3 \times 10^6$  tons of talc was produced in the United States in 1974 (Wells and Clifton, 1977). The industrial uses of talc have resulted in wide distribution of this mineral in air, rain, and snow (Windom, 1969; and Bowes *et al.*, 1977). Talc and its aluminous analog pyrophyllite have also been reported as constituents of suspended matter in ocean waters off the southeastern United States (Pierce *et al.*, 1971), in the Caribbean (Jacobs and Ewing, 1965, 1969), in the Mediterranean (Pierce and Stanley, 1975), and in the South Atlantic (Van Baren and Harmse, 1969; Milliman *et al.*, 1975). Some workers, however, attribute the presence of talc in water samples to contamination during sampling or analysis (Sartori and Tomadin, 1977).

The present study reports the presence and distribution of talc in the shelf waters off the northeastern United States and discusses the possible sources for this mineral.

### METHODS

During August 1978 and August 1979, 66 water samples were collected at 53 locations on the Continental Shelf and upper Slope and later analyzed. The study area extended northward from Wilmington Canyon to the southern Gulf of Maine (Figure 1). A 20-liter sample was taken at each station for mineralogical analysis; sampling depths ranged from 1 to 300 m (Table I). The samples were mounted on filters and frozen immediately after they were collected. In the laboratory, acetone was used to dissolve the filters, and 10% hydrogen peroxide was used to remove the oxidizable organic material. Three samples were also collected at each station and ashed to determine the non-combustible fraction of the suspended material; one near the surface, one at mid-depth, and one near the bottom. To establish the presence of talc in rain water, samples were collected on Cape Cod, Massachusetts, from a storm which occurred during July 1981.

The samples were suction-mounted as oriented aggregates on silver filters and were examined by X-ray powder diffraction as described by Poppe and Hathaway (1979). A technique modified from Biscaye (1965) gave semiquantitative estimates of relative amounts of the clay minerals present. Mixtures of clay minerals spiked with known amounts of talc were used

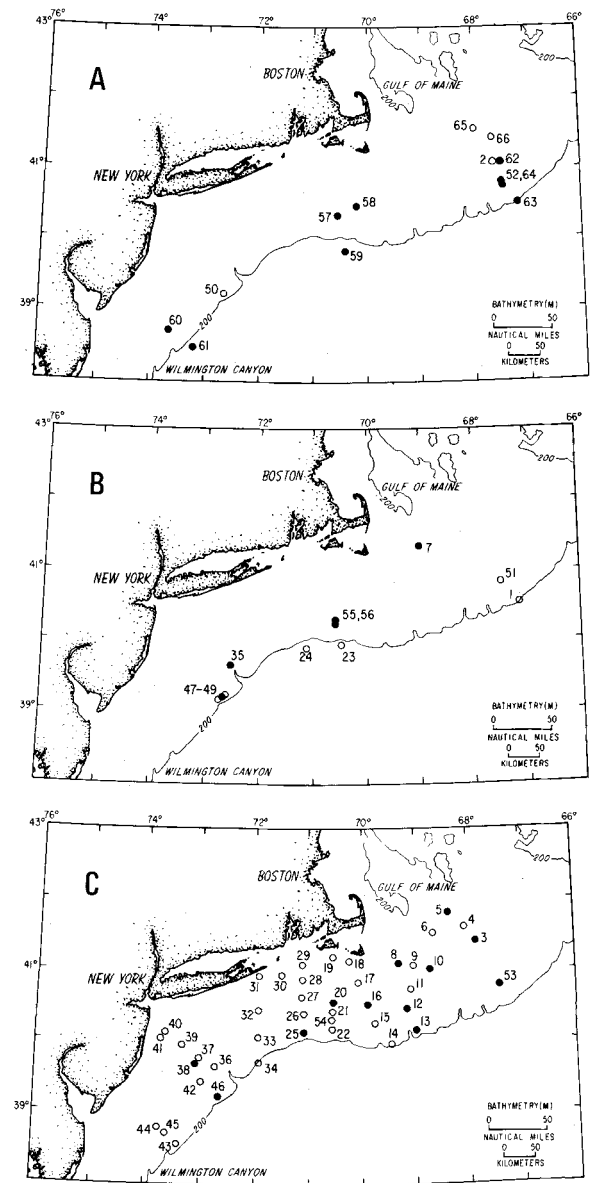


Figure 1. Maps of study area and suspended-matter sample locations. A, near surface samples; B, mid-depth samples; C, near-bottom samples. Solid circles = talc present; open circles = talc not detected.

as references. The identification of talc was based on peaks observed at 9.35 and 3.12 Å which closely approximate the principal diffraction maxima on JCPDS card 13-558.

To prevent the type of contamination reported by Sartori and Tomadin (1977), the use of rubber and plastic instruments and containers was minimized; no samples were left uncovered, and aluminum foil was used to channel the rainwater samples into glass carboys. In all operations the sample processing equipment was washed and rinsed with distilled water between each sample. In addition, three 20-liter blanks of distilled water were placed in the Niskin bottles used during the cruises and agitated for approximately 5 min. These blanks were then passed through the sample processing equipment used aboard ship and in the laboratory; no talc was observed in the blanks.

## RESULTS

A mineral suite consisting of smectites, mixed-layer illite/smectite, mixed-layer chlorite/smectite, chlorite, illite and/or mica, kaolinite, quartz, feldspar, calcite, and talc was found in the suspended particulate matter of the study area (Table 1). The calcite in the samples is likely due entirely to calcite-secreting organisms. With the exception of talc, the mineralogy of this suite closely resembles that of the surficial bottom sediments (Hathaway, 1971). Talc was detected in 26 samples taken from 23 locations (Figure 1). Concentrations of talc ranged up to 9% at station 3; however, most samples where talc was found contained only trace amounts of this mineral. The relative abundance of clay minerals (except talc) in suspension was essentially constant throughout the study area. This consistency was also found for samples from near the bottom where the concentrations of suspended silicates were highest because of resuspension of bottom sediments (Table 1). The uniformity in relative abundance of the major clay minerals throughout the study area and the similarity between the clay mineral composition of suspended and bottom sediments supports the conclusion (Bothner *et al.*, 1981a) that the major clay-mineral groups in the water column originated from resuspension of bottom sediment.

Talc was noted more frequently in surface samples probably because talc is more easily detected in samples that contain low concentrations of resuspended bottom sediments. Samples collected from near the surface (<3 m water depth) had the lowest amounts of nonorganic particulates, yet 9 of 13 (69%) contained detectable quantities of talc. At the mid-depth stations, talc was observed in 5 of 11 samples (45%). Most samples were taken near the bottom, less than 5 m above the sediment-water interface. These samples contained the highest percentage of silicates; however, talc was present in only 12 of 42 samples (29%). Because dilution by other silicates may place it beyond the limits of detection by the sampling and X-ray powder diffraction techniques employed, the frequency of occurrence of talc in the suspended sediments may actually be greater than indicated by the samples analyzed.

Talc was detected in both rain water samples collected on Cape Cod. These samples, labeled RAIN 1 and RAIN 2 in Table 1, contained a clay mineral suite consisting of illite and/or mica, kaolinite, chlorite, talc, and mixed-layer illite/smectite.

## DISCUSSION

As listed above, talc in suspended matter in seawater may be due to: resuspension from bottom sediments, input by the Gulf Stream, shoreline erosion and river drainage of areas containing talc-bearing rocks, and deposition of waterborne or windborne material contributed by industrial and agricultural activities.

Resuspension due to storms, surface waves, and tidal currents is the major present-day source of non-biogenic particulate matter on this Continental Shelf (Bothner *et al.*, 1981a).

However, such a source for the other clay minerals detected does not explain the occurrence of talc in suspension, because talc has not been detected in the bottom sediments of the shelf (Hathaway, 1971). Even if talc were present in the bottom sediments but in amounts too small to be detected, it would have to be concentrated by some mechanism such as winnowing in order to be detectable to the extent that it is in the suspended matter. Inasmuch as talc has a size, shape, and density similar to those of the other clay minerals, it is unlikely that it was selectively winnowed from the bottom sediment and concentrated in the water column.

The sediment-poor rivers of the northeastern United States are also unlikely sources of such amounts of talc. The Delaware, Hudson, and Connecticut Rivers presently empty into large estuarine systems that act as sinks for the river sediment (Meade, 1969). Although the Connecticut River drains an area within which talc is mined, samples collected during a previous study from the lower estuary of the river contained no detectable concentrations of talc (Poppe, 1976). No talc has been reported in shoreline sediments bordering the study area (Hathaway, 1971).

Jacobs and Ewing (1965, 1969) reported talc in the suspended matter of the Caribbean Sea and Gulf of Mexico as possible sources of talc which they found on the southeastern shelf. They used settling rates to show the Gulf Stream to be an unlikely source for talc on the southeastern shelf. Therefore, although Gulf Stream eddies sometimes intrude the region of the northeastern shelf (Morgan and Bishop, 1977), the Gulf Stream is an even less probable source for talc on the northeastern shelf.

Because talc has wide commercial applications, contamination by municipal and industrial wastewaters is a possible source of talc in suspended matter. Sewage sludge is a major source of sediment to the Continental Shelf waters near centers of high population density of the northeastern States, and about half of these sludges is silicate material that is mineralogically similar to the rocks of the source area (Gross, 1972). A sample from the Deer Island sewage outflow off Boston, Massachusetts, did contain traces of talc (Table 1). Talc may be present in the sewage sludge from the New York metropolitan region dumped in New York Bight, but the large amounts of talc relative to other silicates found in the suspended matter, and observations of current directions on the Mid-Atlantic Continental Shelf and on Georges Bank (Butman *et al.*, 1982) argue strongly against sewage disposal as an important source of talc on the outer parts of the Continental Shelf where many of our observations have been made.

Another possible source of talc in the water column is atmospheric fallout resulting from the agricultural use of talc in pesticides. The extent of the distribution of such particulates was demonstrated by Windom (1969) in a study of dust residues from permanent snowfields. Talc was present in every snow sample taken in the northern hemisphere. In addition, talc has been found in samples collected directly from the atmosphere throughout the world. Global fallout results from precipitation by rain and snow, and from gravitational settling. Determinations by Windom *et al.* (1967) showed a fallout of  $2 \times 10^{-6}$  g/cm<sup>2</sup>/yr for talc between latitudes 30° and 60°N. Because the winds at these latitudes are predominantly from the west, talc used in domestic agricultural dusting would be deposited and should be detectable off the eastern coast of the United States. The presence of talc in the rain water samples collected on Cape Cod also supports such an atmospheric source.

We conclude that airborne material is the major source of talc in the suspended matter examined in this study on the basis of: (1) the prominence of talc in previous samples of atmospheric dust; (2) the presence of talc in samples of rain on Cape Cod; (3) the ubiquity of talc in snow samples from the

Table 1. Location and mineralogy of suspended matter samples.<sup>1</sup>

| Station | Depth (m)<br>Sample/<br>water | C/S | S  | C  | I/S | I  | T  | K  | Comments | Lat. (N) | Long. (W) | Noncombust.<br>( $\mu$ g/liter)<br>Sur./m.bot. |
|---------|-------------------------------|-----|----|----|-----|----|----|----|----------|----------|-----------|--|
| 1       | 28/228                        |     |    |    |     |    |    |    | X        | 40°31.6' | 67°08.0'  | 35/ 211/NA                                     |
| 2       | 2/52                          | Tr  |    | 25 | 7   | 43 |    | 25 |          | 41°09.2' | 67°38.8'  | 237/ 336/360                                   |
| 3       | 34/38                         | Tr  |    | 29 | 6   | 39 | 9  | 17 |          | 41°28.3' | 67°52.4'  | 353/ 435/385                                   |
| 4       | 28/32                         |     |    | 26 | 10  | 53 |    | 11 |          | 41°40.7' | 68°02.1'  | 282/ 348/412                                   |
| 5       | 203/205                       |     | Tr | 27 | 2   | 52 | 4  | 14 |          | 41°52.7' | 68°24.2'  | 99/ 223/554                                    |
| 6       | 135/135                       | Tr  |    | 28 | 2   | 56 |    | 14 |          | 41°35.7' | 68°37.7'  | 83/ 234/529                                    |
| 7       | 146/151                       |     |    | 23 | Tr  | 65 | Tr | 11 |          | 41°23.5' | 69°00.2'  | 44/ 132/782                                    |
| 8       | 48/51                         |     |    | 24 | 2   | 60 | 2  | 12 |          | 41°08.9' | 69°19.8'  | 125/ 168/257                                   |
| 9       | 92/96                         |     | Tr | 28 | 3   | 62 |    | 6  |          | 41°06.8' | 69°00.8'  | 128/ 205/330                                   |
| 10      | 51/55                         |     | Tr | 32 | 3   | 53 | 1  | 11 |          | 41°04.5' | 68°44.0'  | 172/ 392/NA                                    |
| 11      | 57/62                         |     |    |    |     |    |    |    | X        | 40°48.1' | 69°0.50'  | 31/ 57/578                                     |
| 12      | 74/77                         |     | Tr | 21 | 2   | 61 | 6  | 9  |          | 40°30.2' | 69°08.2'  | 45/ 57/342                                     |
| 13      | 135/138                       | Tr  |    | 23 | 3   | 39 | Tr | 34 |          | 40°11.5' | 68°59.6'  | NA/ 70/94                                      |
| 14      | 101/103                       |     |    | 32 | Tr  | 55 |    | 13 |          | 40°00.7' | 69°25.0'  | 69/ 81/123                                     |
| 15      | 79/81                         |     |    |    |     |    |    |    | X        | 40°17.5' | 69°44.6'  | 73/ 40/80                                      |
| 16      | 60/63                         |     |    | 28 | 1   | 57 | 1  | 13 |          | 40°34.4' | 69°53.0'  | 67/ 110/547                                    |
| 17      | 22/24                         |     |    |    |     |    |    |    | X        | 40°52.8' | 70°04.0'  | 234/ 205/276                                   |
| 18      | 22/25                         |     |    | 25 | 3   | 54 |    | 18 |          | 41°11.0' | 70°13.1'  | NA/ 300/292                                    |
| 19      | 26/29                         |     |    | 28 | 1   | 57 |    | 14 |          | 41°15.2' | 70°31.7'  | 112/ 234/424                                   |
| 20      | 60/63                         |     |    | 23 | 3   | 69 | Tr | 5  |          | 40°36.6' | 70°30.9'  | 137/ 155/924                                   |
| 21      | 69/72                         |     | Tr | 28 | Tr  | 57 |    | 13 |          | 40°28.5' | 70°32.0'  | 29/ 108/1402                                   |
| 22      | 114/118                       |     | Tr | 29 | 2   | 50 |    | 14 |          | 40°13.0' | 70°31.9'  | 78/ 87/435                                     |
| 23      | 287/421                       |     |    | 33 | 3   | 50 |    | 13 |          | 39°56.6' | 70°31.7'  | 8/ 70/11                                       |
| 24      | 300/470                       |     |    |    |     |    |    |    | X        | 39°56.4' | 71°05.8'  | NA/ 54/47                                      |
| 25      | 125/127                       |     |    | 25 | 4   | 60 | Tr | 11 |          | 40°10.9' | 71°03.7'  | 101/ 48/449                                    |
| 26      | 81/84                         |     |    | 31 | Tr  | 60 |    | 8  |          | 40°25.2' | 71°03.6'  | 71/ 113/942                                    |
| 27      | 62/64                         |     | Tr | 31 | Tr  | 57 |    | 11 |          | 40°40.3' | 71°06.2'  | 45/ 133/1001                                   |
| 28      | 51/51                         |     |    | 34 | 1   | 51 |    | 14 |          | 40°56.0' | 71°05.7'  | 36/ 378/414                                    |
| 29      | 33/35                         |     |    |    |     |    |    |    | X        | 41°08.0' | 71°06.0'  | 36/ 176/130                                    |
| 30      | 49/53                         |     | I  | 25 | 2   | 56 |    | 16 |          | 40°59.5' | 71°30.1'  | 40/ 38/653                                     |
| 31      | 38/40                         |     |    | 30 | Tr  | 61 |    | 9  |          | 40°59.5' | 71°55.1'  | 33/ 70/194                                     |
| 32      | 64/68                         |     | Tr | 24 | Tr  | 60 |    | 15 |          | 40°29.6' | 71°55.1'  | 25/ 88/491                                     |
| 33      | 81/84                         |     |    | 18 | 3   | 69 |    | 10 |          | 40°07.5' | 71°54.9'  | 13/ 109/442                                    |
| 34      | 181/186                       |     | Tr | 26 | 2   | 56 |    | 15 |          | 39°46.0' | 71°54.5'  | 21/ 97/168                                     |
| 35      | 145/156                       |     |    | 27 | 2   | 58 | Tr | 13 |          | 39°40.3' | 72°29.7'  | 54/ 65/315                                     |
| 36      | 70/76                         |     |    | 29 | 1   | 57 |    | 13 |          | 39°40.0' | 72°42.1'  | 30/NA/188                                      |
| 37      | 78/80                         | Tr  |    | 27 | Tr  | 59 |    | 14 |          | 39°47.4' | 72°59.5'  | 27/ 44/585                                     |
| 38      | 51/54                         |     |    | 27 | 4   | 58 | Tr | 11 |          | 39°43.8' | 73°04.1'  | 32/ 45/403                                     |
| 39      | 67/71                         |     |    | 33 | 7   | 50 |    | 13 |          | 39°57.8' | 73°18.4'  | 8/ 49/1692                                     |
| 40      | 69/74                         |     |    |    |     |    |    |    | X        | 40°08.0' | 73°37.5'  | 24/ 63/286                                     |
| 41      | 32/34                         |     |    | 30 | 2   | 59 |    | 9  |          | 40°0.40' | 73°41.0'  | 28/ 15/306                                     |
| 42      | 58/61                         |     |    | 28 | 3   | 58 |    | 11 |          | 39°29.4' | 72°58.0'  | 16/ 52/220                                     |
| 43      | 92/95                         |     | Tr | 29 | 1   | 61 |    | 9  |          | 38°33.5' | 73°23.2'  | 7/ 24/NA                                       |
| 44      | 49/51                         |     |    |    |     |    |    |    | X        | 38°48.4' | 73°46.0'  | 7/ 75/294                                      |
| 45      | 57/61                         |     |    | 29 | 3   | 54 |    | 14 |          | 38°43.5' | 73°37.9'  | 14/ 23/90                                      |
| 46      | 127/129                       |     |    | 32 | 1   | 59 | Tr | 8  |          | 39°14.3' | 72°39.6'  | 8/ 16/284                                      |
| 47      | 75/129                        |     |    | 26 | Tr  | 59 |    | 15 |          | 39°14.3' | 72°39.7'  | NA/ 30/186                                     |
| 48      | 28/131                        |     |    |    |     |    |    |    | Y        | 39°14.4' | 72°39.5'  | 6/ 36/310                                      |
| 49      | 57/131                        |     | Tr | 26 | 1   | 61 |    | 11 |          | 39°14.4' | 72°39.5'  | 7/ 51/271                                      |
| 50      | 1/128                         |     |    |    |     |    |    |    | X        | 39°41.3' | 72°39.7'  | 15/ 28/258                                     |
| 51      | 12/82                         |     |    |    |     |    |    |    | X        | 40°51.1' | 67°23.4'  | 11/ 133/130                                    |
| 52      | 2/86                          |     |    |    |     |    |    |    | Y        | 40°51.0' | 67°22.5'  | NA/ 53/173                                     |
| 53      | 84/86                         |     |    |    |     |    |    |    | Y        | 40°51.0' | 67°22.6'  | 26/ 51/154                                     |
| 54      | 92/94                         |     | Tr | 31 | 2   | 56 |    | 10 |          | 40°21.0' | 70°34.3'  | 38/ 44/1173                                    |
| 55      | 59/94                         |     |    | 26 | 7   | 50 | Tr | 17 |          | 40°20.7' | 70°34.0'  | 15/ 495/918                                    |
| 56      | 35/93                         |     | I  | 27 | 10  | 48 | Tr | 14 |          | 40°21.0' | 70°34.3'  | 16/ 33/886                                     |
| 57      | 2/94                          |     |    |    |     |    |    |    | Y        | 40°20.6' | 70°33.6'  | 22/ 173/930                                    |
| 58      | 2/68                          |     | I  | 21 | 2   | 62 | 3  | 10 |          | 40°29.5' | 70°12.6'  | NA/NA/NA                                       |
| 59      | 2/815                         |     |    |    |     |    |    |    | Y        | 39°51.0' | 70°25.1'  | NA/NA/NA                                       |
| 60      | 2/62                          |     | Tr | 19 | 5   | 61 | 4  | 10 |          | 38°42.1' | 73°39.9'  | NA/NA/NA                                       |
| 61      | 2/855                         |     |    |    |     |    |    |    | Y        | 38°29.0' | 73°14.1'  | NA/NA/NA                                       |
| 62      | 2/63                          |     |    |    |     |    |    |    | Y        | 41°02.2' | 67°32.7'  | NA/NA/NA                                       |
| 63      | 2/255                         |     |    |    |     |    |    |    | Y        | 40°31.4' | 67°06.5'  | NA/NA/NA                                       |
| 64      | 2/87                          |     |    |    |     |    |    |    | Y        | 40°51.4' | 67°21.3'  | NA/NA/NA                                       |

Table 1. Continued.

| Station | Depth (m)<br>Sample/<br>water | C/S | S  | C  | I/S | I  | T  | K  | Com-<br>ments | Lat. (N) | Long. (W) | Noncombust.<br>( $\mu\text{g/liter}$ )<br>Sur./m/bot. |
|---------|-------------------------------|-----|----|----|-----|----|----|----|---------------|----------|-----------|---|
| 65      | 2/37                          | Tr  | Tr | 23 | 3   | 63 |    | 9  |               | 41°36.4' | 67°59.7'  | NA/NA/NA  |
| 66      | 3/35                          |     |    | 23 | 3   | 58 |    | 14 |               | 41°29.3' | 67°39.6'  | NA/NA/NA  |
| RAIN 1  |                               |     |    | 16 | 2   | 45 | 14 | 23 |               | 41°32.0' | 70°39.0'  | NA/NA/NA  |
| RAIN 2  |                               |     |    |    |     |    |    |    | Y             | 41°32.0' | 70°39.0'  | NA/NA/NA  |
| DI      |                               |     |    | 23 | 6   | 61 | Tr | 9  |               | 42°21.2' | 70°57.4'  | NA/NA/NA  |

Relative percentages determined by X-ray powder diffraction techniques. Tr = <1%. X = concentration of layer silicates below limits of detection and talc not detected. Y = talc present and concentration of other layer silicates below limit of detection. NA = data not available. RAIN 1 and RAIN 2 = rain water samples collected on Cape Cod. DI was collected from the Deer Island Sewage Outflow off Boston, Massachusetts.

<sup>1</sup> C = chlorite; S = smectite; C/S = mixed-layer chlorite/smectite; I = illite and/or mica; I/S = mixed-layer illite/smectite; T = talc; K = kaolinite; Noncombust. = noncombustible in  $\mu\text{g/liter}$  for surface, midpoint, and bottom samples.

northern hemisphere; (4) the wide occurrence of talc in near-surface water samples. We discount waterborne material as a major source on the basis of: (1) the absence of observations of talc in bottom sediments and, therefore, the unsuitability of these sediments as a source of talc in the water column by resuspension; (2) the absence of observations of talc in river samples, and the minor quantities of riverborne sediment that reach the Continental Shelf of the northeastern United States under Holocene conditions; (3) the localized nature of artificial deposition of sewage sludge, and the lack of suitable ocean currents to disperse such materials to many areas where talc is prominent in suspended matter; (4) the improbability that winnowing in the water column concentrates talc from materials introduced by fluvial, resuspension, or artificial processes.

If talc is present in the suspended matter why is it not observed in the bottom sediments? The apparent absence of talc in marine bottom sediments of the Continental Shelf off the northeastern United States is probably due to the fact that it has been used extensively in industry for only the past 100 years and has not yet accumulated to concentrations above analytical detection limits. Estimates of sedimentation rates on the Continental Shelf range from erosion or nondeposition in areas covered by relict sands to 25–50 cm/1000 yr at the "Mud Patch" south of Martha's Vineyard (Bothner *et al.*, 1981b). In addition, this recently deposited sediment is continually reworked by bioturbation and currents. Depths of mixing to 28 cm over 100 years in the study area have been reported, and much faster mixing is evident from profiles of Pb<sup>210</sup> in the upper 10 cm (Bothner *et al.*, 1981b). Such mixing would dilute deposited talc to concentrations below the detection thresholds of X-ray powder diffraction.

#### ACKNOWLEDGMENTS

We thank Frederick L. Sayles for his constructive comments and Richard Rendigs for his assistance in collecting the samples.

U.S. Geological Survey

Woods Hole, Massachusetts 02543

LAWRENCE J. POPPE

JOHN C. HATHAWAY

CAROL M. PARMENTER

#### REFERENCES

- Biscaye, P. E. (1965) Mineralogy and sedimentation of recent deep-sea clay in the Atlantic Ocean and adjacent seas and oceans: *Geol. Soc. Amer. Bull.* **76**, 803–832.
- Bothner, M. H., Parmenter, C. M., and Milliman, J. D. (1981a) Temporal and spatial variations in suspended matter in shelf and slope waters off the northeastern United States: *J. Est. Coast. Shelf Sci.* **13**, 213–234.
- Bothner, M. H., Spiker, E. C., Johnson, P. P., Rendigs, R. R., and Aruscavage, P. J. (1981b) Geochemical evidence for modern sediment accumulation on the Continental Shelf off southern New England: *J. Sediment. Pet.* **51**, 281–292.
- Bowes, D. R., Langer, A. M., and Rohl, A. N. (1977) Nature and range of mineral dust in the environment: *Phil. Trans. Royal Soc., London A.* **286**, 593–610.
- Butman, B., Beardsley, R. C., Magnell, B., Vermersch, J. A., Schlitz, R., Limeburner, R., Wright, W. R., and Noble, M. A. (1982) Recent observations of the mean circulation on Georges Bank: *Woods Hole Ocean. Inst. Contrib.* **4722**, 33 pp.
- Gross, M. G. (1972) Geologic aspects of waste solids and marine waste deposits, New York metropolitan region: *Geol. Soc. Amer. Bull.* **83**, 3163–3176.
- Hathaway, J. C. (1971) Data file, continental margin program, Atlantic coast of the United States. Vol. 2. Sample collection and analytical data: *Woods Hole Ocean. Inst., Ref. No. 71-15*, 2, 496 pp.
- Jacobs, M. B. and Ewing, M. (1965) Mineralogy of particulate matter suspended in sea water: *Science* **149**, 179–180.
- Jacobs, M. B. and Ewing, M. (1969) Mineral source and transport in waters of the Gulf of Mexico Caribbean sea: *Science* **163**, 805–809.
- Meade, R. H. (1969) Landward transport of bottom sediments in estuaries of the Atlantic coastal plain: *J. Sediment. Pet.* **39**, 222–234.
- Milliman, J. D., Summerhayes, C. P., and Barrettae, H. T. (1975) Oceanography and suspended matter off the Amazon River February–March 1973: *J. Sediment. Pet.*, **45**, 189–206.
- Morgan, C. W. and Bishop, J. M. (1977) An example of Gulf Stream eddy-induced water exchange in the mid-Atlantic bight: *J. Phys. Ocean.* **7**, 472–479.
- Pierce, J. W., Nelson, D. D., and Colquhoun, D. J. (1971) Pyrophyllite and talc in the waters off the southeastern United States: *Mar. Geol.* **11**, 9–15.
- Pierce, J. W. and Stanley, D. J. (1975) Suspended sediment concentration and mineralogy in the central and western Mediterranean and mineralogic comparison with bottom sediment: *Mar. Geol.* **19**, M15–M25.
- Poppe, L. J. (1976) Mineral variation in the source sediments to Long Island Sound: MS thesis, Univ. Connecticut, Storrs, Connecticut, 73 pp.
- Poppe, L. J. and Hathaway, J. C. (1979) A metal membrane mount for X-ray powder diffraction: *Clays & Clay Minerals* **27**, 152–153.
- Sartori, R. and Tomadin, L. (1977) Origin of talc in the Ionian Sea waters: *Mar. Geol.* **25**, 13–18.

- Van Baren, F. A. and Harmse, H. J. von M. (1969). Surinam and the African Continent: a clay mineralogical study of sea water solids: *J. Sediment. Pet.* **39**, 1588–1639.
- Wells, J. R. and Clifton, R. A. (1977) Talc, soapstone, and pyrophyllite: in *Minerals Yearbook, 1975, Vol. 1*. A. E. Schreck, ed., U.S. Bur. Mines, Washington, D.C., 1359–1365.
- Windom, H., Griffin, J., and Goldberg, E. D. (1967) Talc in atmospheric dust: *Envir. Sci. Tech.* **1**, 923–926.
- Windom, H. L. (1969) Atmospheric dust records in permanent snowfields: implications to marine sedimentation: *Geol. Soc. Amer. Bull.* **80**, 761–782.
- (Received 23 September 1981; accepted 14 September 1982)