Reports

Suspended Particulate Matter: Concentration in the Major Oceans

Abstract. *Quantitative data from over 500 concentrates of suspended particulate material has been summarized statistically for the Atlantic, Pacific, and Indian oceans, the Gulf of Mexico, and the Caribbean Sea. From clear ocean water a majority of samples were in the range of 0 to 9.9 milligrams per 200 liters and the next largest number were in the range of 10 to 19.9 milligrams per 200 liters. Certain areas of cloudy or nepheloid water, observed photographically, contain relatively more samples in heavier concentration ranges and have larger mean values than clear ocean water.*

Suspended particulate matter in seawater has been the subject of over 3 years of investigations. More than 500 deep and surface water barrels have been taken during the *Robert D. Conrad* cruises 9, 10, and 11 and *Vema* cruises 22, 23, and 24 in conjunction with continuous surface to bottom photographs of sediment distribution in suspension (Figs. 1 and 2). The 200-liter water barrel was used to obtain samples large enough for x-ray diffraction and optical analysis. Water barrels were attached to a trawl wire at chosen distances above the sediment-coring apparatus. The water samples were centrifuged on board ship to recover the solid material at the rate of a liter per minute in a Centrico KDD-605 continuous flow, four-bowl centrifuge operated at 10,000 rev/min, developing 9000*g* at the periphery of the outer bowl and 7000*g* at the innermost chamber.

In the laboratory, the samples were washed with distilled water until the decantation yielded a negative chloride test, then dried at 100°C, and weighed. Water-sedimented slides were made of all samples for optical study. Contaminated samples (determined on the basis of observations from the ships' logs, optical examination, or x-ray diffraction analysis) were discarded. Total sample weights are reported (Table 1), inclusive of biogenic remains of animal and plant life and mineral and rock fragments of crystalline or amorphous nature. Near-surface samples (0 to 180 m) are omitted to make possible a better description of the concentration of suspended material in the pelagic realm, below the continental shelves where many sedimentation mechanisms are active, and away from nearshore influences and river deposition.

Frequency distribution diagrams of the weights of solid material recovered from 200-liter water samples for several major oceans and seas show that most samples occur in low concentration ranges. For the South Pacific, all the sample weights were under 20 mg/200 liters, indicating little material in suspension. The clarity of this water was also observed during nephelometer studies of light scattering by suspended particles. With few exceptions (6 out of 145), North Pacific samples weigh under 20 mg/200 liters and have a similar frequency distribution. Histograms for the North and South Atlantic show a concentration of samples in the range of less than 20 mg/200 liters for clear water, but they also show more of a spread of sample concentration to the heavier weight ranges. The differences in the frequency distributions of concentrations of particulate matter in the Atlantic and Pacific oceans are significant.

Photographic observations have defined an area off the continental slope and rise of North America in the North Atlantic (*1*) and another in the Argentine Basin in the South Atlantic (*2*) where there are denser concentrations of particulate matter in suspension, or nepheloid layers, in the lower part of the water column. Previous observations (*1*) of the North Atlantic nepheloid layer were made in a region with approximate coordinates, 25° to 40°N and 65° to 75°W. Twelve water barrels were obtained within this area, collected from 20 to 361 m from the bottom, where bottom depths range from 2553 to 5724 m. The concentration of suspended particulate matter from these samples has a mean value of 14.0 mg/200 liters, as compared with 9.8 mg/200 liters for clear North Atlantic water. In the South Atlantic, 15 samples taken from the basin enclosed by the 4575-m (2500-fm) contour (southeast of the mouth of the La Plata River) within 13 to 29 m from the bottom had a mean concentration of 11.2 mg/200 liters. Frequency distribution graphs of the concentration of particulate material suspended in nepheloid water have a different appearance than do those for ocean water in general. Nepheloid water yields relatively more samples in heavier concentration ranges.

Table 1. Summary of weight-concentration data of suspended particulate matter in the major oceans.

Water body	Samples (No.)	Obs. range (mg/200 liters)	Mean (mg/200 liters)
N. Atlantic	88	0.1–49.5	9.8
S. Atlantic	52	0.3–39.4	10.2
N. Pacific	145	0.1–30.5	7.5
S. Pacific	78	0.9–17.3	5.9
Indian	37	1.8–35.4	14.3
Caribbean Sea	25	0.1–27.8	8.1
Gulf of Mexico	11	2.5–38.6	13.2

In another study of suspended particulate matter from the open ocean, samples were collected from the surface waters of the North Atlantic for investigation of the eolian contribution to deep-sea sediments (*3*). The concentration of the suspended matter ranged from 0.04 to 0.15 mg/liter. This range (8 to 30 mg/200 liters) is in agreement with data presented here.

As part of a project to construct a scale of photographic light intensity corresponding to absolute measurement of particle concentration in suspension, particulate samples collected on *Conrad* cruise 11 were found to have about 0.1 mg/liter for the nepheloid layer (*4*). This concentration (20 mg/200 liters) toward the continental slopes tions presented here. From Jerlov's light-scattering data, the oceanic concentration of suspended matter has been estimated (*5*) as 0.056 mg/liter (11.2 mg/200 liters).

This low concentration of suspended solids in the open sea is at variance with the data of Lisitzin (*6*), and efforts to determine possible causes of the discrepancy are still being made. For surface waters of the Indian Ocean, 0.5 to 1.0 g/m^3 (100 to 200 mg/200 liters) was reported as typical, with 2.0 to 10.0 g/m^3 (0.4 to 2.0 g/200

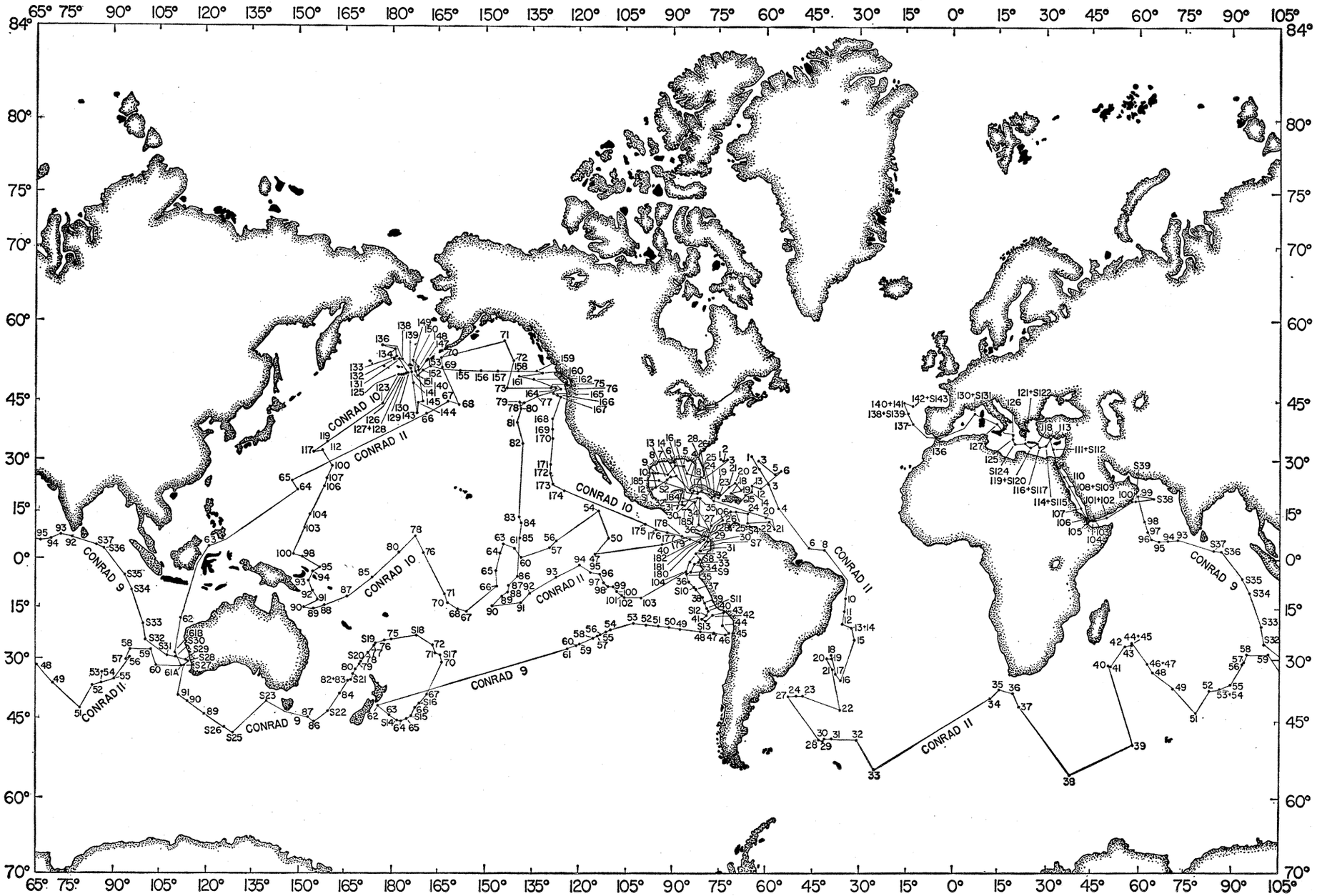

Fig. 1. Locations of water samples taken on *Robert D. Conrad* cruises 9, 10, and 11.

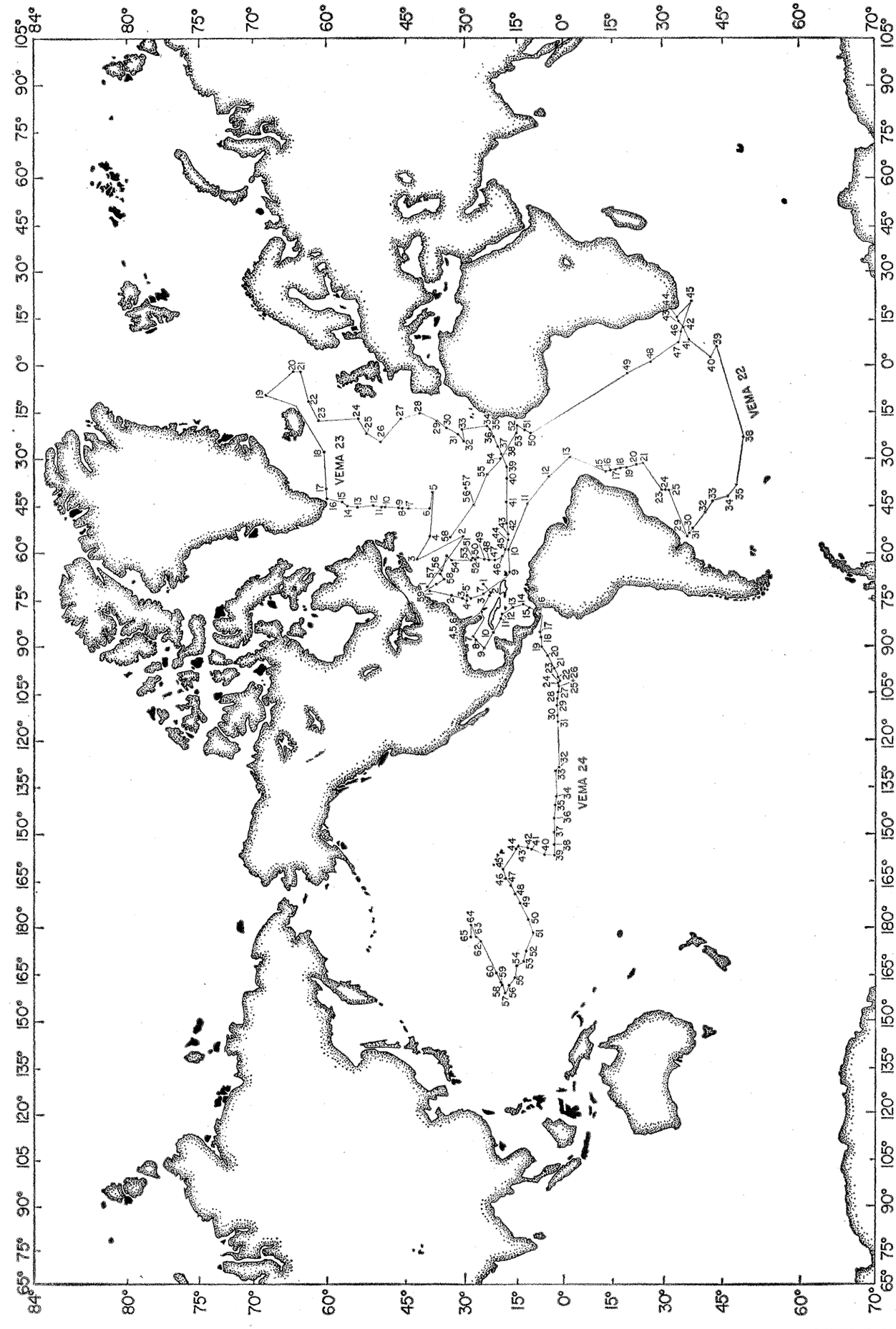

Fig. 2. Locations of water samples taken on *Vema* cruises 22, 23, and 24.

Table 2. Concentration data for suspended particulate material in Arctic Ocean water at Arctic drifting ice station, T-3.

Water mass	Dry weight (mg/200 liters)	Position of sample from surface (m)	Water depth (m)	Latitude	Longitude
Surface	6.4	12	1537–1735	78°46′N	175°25′W
Pacific (maximum T)	3.76	75	2500–2528	79°25′N	171°25′W
Pacific (minimum T)	3.58	155	2286–2313	79°24′N	173°57′W
Atlantic	9.76	500	2184–2284	79°16′N	175°05′W
Deep water	1.16	1000	2498–2522	79°37′N	171°41′W
Deep water	1.92	2000	2250–2407	79°43′N	173°38′W
Deep water	1.68	2210	2310	79°39′N	171°52′W
Deep water	1.90	2260	2310	79°39′N	171°56′W
Deep water	2.0	2302	2304	79°38′N	172°00′W

liters) toward the continental slopes (*6*). At the continental slopes, "clouds" were observed with a larger content of particles in suspension, which are suggestive of nepheloid water.

Contamination, the addition of something foreign to the sample, is probably the greatest potential source of error. A concerted effort has been made for cleanliness in handling the water barrel, the pump and hoses to it, and the core pipe. Problems inherent to the sampling process prompted development of a recorder which gives a positive check on the depth of closing of the door of the barrel. The completeness of the recovery of the solids from the centrifugation process is checked by running the water remaining in the centrifuge bowl through Millipore filters. The amount of material that collects on these filters appears to be negligible.

Recent sampling with a 200-liter water barrel at the Arctic drifting ice station, T-3, provides a useful comparison with the shipboard sampling. At T-3, there is no core pipe, no storage tank, no pump or hoses to clean, and since the barrel used at T-3 has an air vent at the top and a spigot at the bottom, there is far less chance of contamination. Temperature and salinity define the stratification of four water masses (*7*) at the Arctic station, surface water, Pacific water, Atlantic water, and deep water. The concentrations of the particulate matter suspended in the Atlantic and Pacific water masses sampled at T-3 (Table 2) fall in the range of 0 to 9.9 mg/200 liters. The correlation of the T-3 value for Atlantic water, 9.76 mg/200 liters, with the mean value for the North Atlantic, 9.8 mg/200 liters is notable.

The mean values for clear ocean water indicate the South Pacific has the least amount of solids in suspension, the quantity increasing in the North Pacific, then the North Atlantic. and is greatest in the South Atlantic. Certain areas of cloudy, or nepheloid, water have been shown, by photographically recording light scattering and by sample weight, to contain greater concentrations of sedimentary material in suspension than found in clear ocean water.

To this picture of sediment distribution in suspension, seismic profiles add the aspect of sediment stratification from the sea bottom to the crystalline basement rock. It appears that where a thick accumulation of pelagic sediments occurs, there is a nepheloid layer above, extending up from the sea bottom several hundred meters. Observations (*8*) indicate that oceanic deposition occurs in the nepheloid layer. The relationship is significant because it is part of the sedimentation process which may have been active for hundreds of millions of years. Areas receiving vast accumulations of sediments today, such as the North American Basin or the Argentine Basin, may have continued to do so throughout one and perhaps part of two geologic eras.

The pelagic sediments found in these basins have many origins, terrigenous, volcanic, extraterrestrial, skeletal, or chemical precipitation; fine grain-size, however, is their prevailing characteristic. Material of less than one micron in size, especially clay minerals, is found in even the clearest water of the mid-ocean. Because of their size and shape, clay mineral flakes can be carried in suspension for long periods of time by currents and circulation of the deep sea. Similarly lutite-size material half-settled and half-suspended at the sediment-water interface may be disturbed, resuspended, and reactivated into a lutite flow, a fine-grained analog of a turbidity flow. Such a process could explain the distribution of pelagic sediments. The flow would follow the bottom topography, transported by the movement of bottom water, and produce deposits of colloidal-size particles that would blanket and eventually smooth out basement irregularities (*9*) exactly as seismic profiles portray pelagic stratification.

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Fossil Deep-Sea Channel on the Aleutian Abyssal Plain

Abstract. *The discovery of a leveed deep-sea channel whose axial gradient reverses near the Aleutian trench supports the hypothesis that the downbowing of the trench interrupted the turbidity current processes that constructed the Aleutian abyssal plain.*

A study of fathograms (*1*) from Environmental Science Services Administration Seamap surveys has revealed a deep-sea channel which trends northeast to southwest for a distance of 370 km on the Aleutian abyssal plain south of the Aleutian trench (Fig. 1). The channel, here named Seamap channel, is unusual in that it slopes downward from a summit located about midway from