# Reports

## Seasonality and Interaction of Biogenic and Lithogenic Particulate Flux at the Panama Basin

Abstract. *Time-series sediment traps were deployed for an entire year at three depths (890, 2590, and 3560 meters) at a deepwater station (3860 meters) in the Panama Basin. The amount of horizontal and lithogenic particulate material arriving at the three depths was seasonally pulsed and directly reflected changes in surface primary production. Two spikes of organic flux were simultaneously recorded at all three depths: (i) a period of high productivity during regional upwelling in February through March and (ii) an unusual bloom of a single species of coccolithophorid during June through July. This latter spike delivered approximately 25 grams of coccolith per square meter of area at a depth of 3860 meters during less than 60 days. The flux of lithogenic particles increased with increasing depth and was seasonally correlated to surface production and current direction, and not to the detritus discharged in river flow. The data suggest that suspended clays are efficiently scavenged from the water column by rapidly sinking organic aggregates.*

The flux of particulate matter to the deep ocean has recently stimulated interdisciplinary interest (*1*). Although sediment traps have been used in a number of studies to collect particles settling through the water column, very few data exist on the temporal and seasonal variation in particulate flux, especially in deep water (*2, 3*). How much organic matter produced in the euphotic zone is transported to the deep sea, and by what means? How do biogenic and lithogenic particles interact during settling? Some of these questions can be answered if a spike of particle input can be traced, over time, from the surface to deep water.

I chose to investigate temporal variations in particle flux to deep water in the Panama Bight. During January through March, while the Inter-Tropical Convergence Zone (ITCZ) moves to its most southerly location, northerly wind speed reaches its maximum over the Panama Isthmus, generating significant regional upwelling and a conspicuous peak of primary production over the northern bight. Water runoff from the western slopes of the Cordillera de los Andes and coastal plain along the bight increases sharply at the beginning of April. These changes with defined pulses occur predictably each year (Fig. 1) (*4*).

Honjo *et al.* have developed sediment traps that can be used to collect settling particles in 2-month time increments (*5*). A mooring array with three such time-series sediment traps was deployed at 890, 2590, and 3560 m below the surface at a station in the Panama Bight (5°22′N, 85°35′W; 3860 m) from 3 December 1979 to 2 December 1980. The timing to start each collecting increment was accurately synchronized.

There were two peaks of mass flux at all depths, February through March and June through July. Flux was minimal during December through January and very large during June through July at all depths (Fig. 2). The large flux of organic carbon during February through March was subequal at all depths; 16.1 to 18.6 mg $m^{-2}$ $day^{-1}$. This result indicates that most of the particulate organic carbon originating in the euphotic layer during the March productivity peak reaches the deep layer rapidly, at least within a 2-month interval. The mass flux of other biogenic particles including planktonic foraminiferal tests, opaline shells, and fecal pellets showed maximum flux during the same period.

The prominent mass flux maxima occurred during June through July at all depths simultaneously, with the greatest magnitude in the shallowest trap (Fig. 2). The rate of particulate flux at 890 m during this period was 1.7 g $m^{-2}$ $day^{-1}$, which was unequaled by any other primary mass flux assessment in the deep open sea. Carbonate accounted for 93 percent of the total mass flux at 890 m and for 85 and 62 percent at 2590 and 3560 m, respectively. Nearly all the carbonate at all depths was in the form of a single species of coccolithophorid, *Umbellicosphaera sibogae*. During the other time periods, *U. sibogae* was a minor constituent of the living coccolithophorid community and of the flux.

The sediment collected during June through July consisted of macro-aggregates (> 0.5 mm) composed of diversified biogenic particles and innumerable

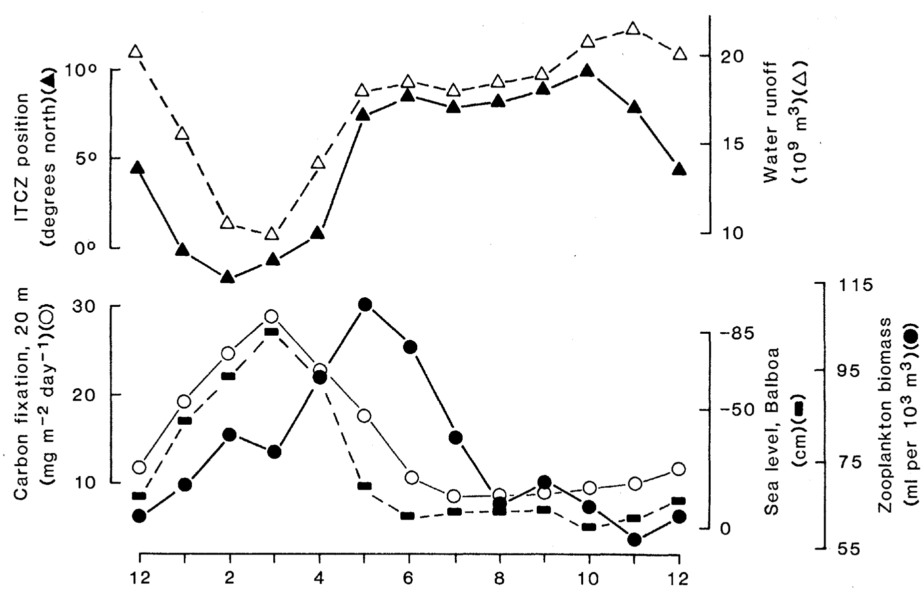


Fig. 1. Relation between monthly climate and ocean productivity criteria in the Panama Bight (*4*). The ITCZ position is along 80°W. Forsbergh's estimations of monthly water runoff volume from the north watershed area with direct access to the bight (*4*) are given. The assessment station for organic carbon fixation was at approximately 7°N, 79°W, north of the mooring station. Zooplankton biomass was estimated from the entire bight.


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clay particles, all cemented together in an organic mucus that was associated with *U. sibogae*. Neither the direct cause nor the geographical extent of the coccolithophorid bloom (*6*) is known at this time. During June through July, of the 100 percent of *U. sibogae* delivered at 890 m, 41 and 22 percent arrived at 2590 and 3560 m, respectively. The decrease of flux with depth may be due to a combination of horizontal diffusion and vertical settling of the coccolithophorid patch (*7*). A relatively strong easterly deep current at approximately 2000 m was recorded at the mooring site during the previous summer (*3*). The areal extent of this coccolithophorid patch was probably relatively small compared to the entire area of the northern bight. In contrast, the February–March bloom provided quasi-equal fluxes of organic carbon at all depths, an indication that the high surface productivity associated with the regional upwelling during this period covered a major area of the northern bight.

The sedimentation of mineral particles (clay, quartz, and feldspar particles) also showed seasonal variation but followed a pattern different from that of the biogenic flux (Fig. 2). Lithogenic particles accounted for 2 to 15 percent of the total mass flux at 890 m but for 25 to 60 percent at 3560 m. The absolute magnitude of the lithogenic flux increased dramatically with depth during all periods. During June through July, the flux of mineral particles to 3560 m was 216 mg $m^{-2}$ $day^{-1}$, seven times as large as the amount caught at 890 m. A large fraction of these excess lithogenic particles did not originate from the surface waters (*8*).

The majority of mineral particles consisted of beidellite (a smectite clay). Beidellite is found on the Pacific side of the continental slope off Costa Rica, northwest of the mooring station (*9*). Fine lithogenic particles were probably resuspended from the slope and laterally transported to the station by the westerly undercurrent (*3*). The coccolithophorid mucus probably plays a major role in the vertical transport of fine lithogenic particles by scavenging and agglutinating them while they are settling through the water column. The sinking speed of aggregates would be accelerated by the increase in their density contrast with water caused by the addition of heavier lithogenic particles. These factors would give rise to the higher lithogenic flux in deeper traps, particularly during the period in which a large quantity of mucus is available. A similar depthward increase of lithogenic particle flux collected during the February–March upwelling season may also be due to aggregated sedimentation. The zooplankton production peak in this area did not coincide with the lithogenic sedimentation maximum (Figs. 1 and 2).

The lithogenic flux cycle at the mooring site was not related to the amount of river water discharged from the coastal area (Fig. 1). The composition of clay minerals remained unchanged throughout the year (*10*); beidellite, an authigenic mineral, was the major constituent throughout the year at all three depths. This observation suggests that the terrigenous lithogenic discharge does not reach the mooring site directly, approximately 300 km from the major estuaries, immediately after the discharge but is contained within a relatively narrow zone near the coast (*4*). On the other hand, biogenic productivity has a profound effect upon the sedimentation cycle of lithogenic particles at this station.

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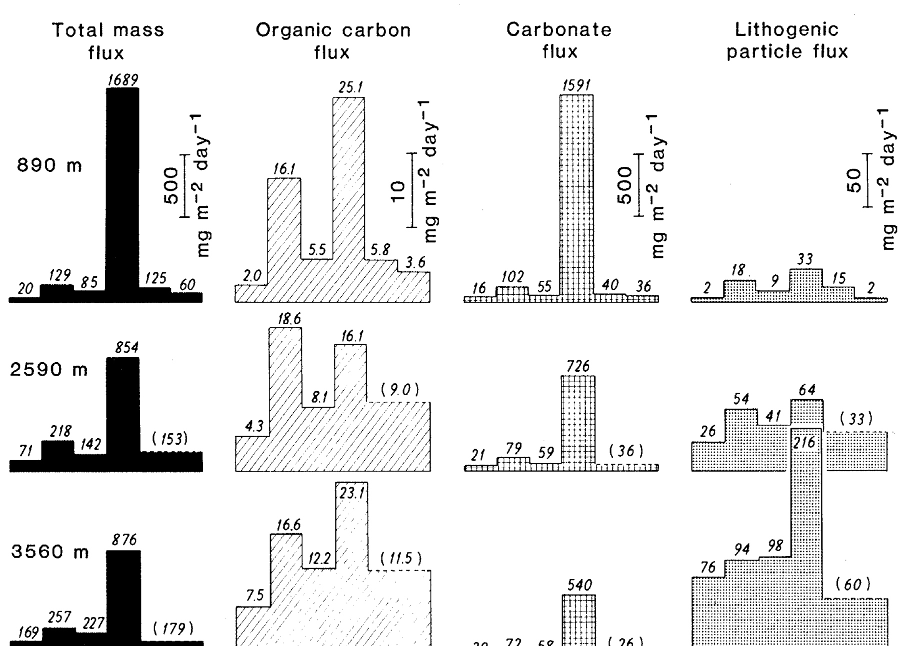


Fig. 2. Total dry mass flux, organic carbon (combustion-infrared detection) flux, carbonate (acetic acid leaching) flux, and lithogenic (combustion residue and x-ray) flux between 3 December 1979 and 2 December 1980 at station PB2 (5°22′N, 85°35′W). Months in 1979 and 1980 are given numerically along the bottom axis. Vertical scales are different except for the total mass and carbonate fluxes. A sample collector failed to rotate in one period at both the 2590-m and 3560-m traps (dotted lines, values in parentheses). The flux from August through November is assumed to be divided equally in the two 2-month increments.

### References and Notes

1. P. H. Wiebe, S. H. J. Boyd, C. L. Winget, *J. Mar. Res.* **34**, 341 (1976); G. T. Rowe and W. D. Gardner, *ibid.* **37**, 581 (1979); G. A. Knauer, J. H. Martin, K. W. Bruland, *Deep-Sea Res.* **26**, 98 (1979); S. Honjo, *J. Mar. Res.* **38**, 53 (1980); P. G. Brewer, Y. Nozaki, D. W. Spencer, A. P. Fleer, *ibid.*, p. 703; K. R. Hinga, J. M. Sieburth, G. H. Heath, *ibid.* **37**, 557 (1979).
2. W. G. Deuser, E. H. Ross, R. F. Anderson, *Deep-Sea Res.* **28A**, 495 (1981).
3. S. Honjo, D. W. Spencer, J. W. Farrington, *Science* **216**, 516 (1982).
4. E. D. Forsbergh, *Bull. Inter.-Am. Trop. Tuna Comm.* **14**, 49 (1969).
5. The basic configuration of the trap used in this study is the Parflex Mark II with a 1.5-$m^2$ opening [S. Honjo, J. Connell, P. Sachs, *Deep-Sea Res.* **27**, 745 (1980)].
6. F. Bernard, *Deep-Sea Res.* **1**, 34 (1953); T. J. Smayda, *Oceanogr. Mar. Biol. Annu. Rev.* **8**, 939 (1970); B. Bodungen, K. Brockel, V. Smetacek, B. Zeitzschel, *Kiel. Meeresforsch.* **5**, 49 (1981).
7. Scanning electron microscopic observations indicated no radical dissolution of coccoliths in deeper traps. Coccolith flux during February through March did not change with depth. I regard dissolution, therefore, as a minor cause for decreasing fluxes with depth during June through July.
8. Particulate aluminum fluxes at the surface of the North Atlantic were estimated to be about 0.14 mg $m^{-2}$ $day^{-1}$ [P. Buat-Menard and R. Chesselet, *Earth Planet. Sci. Lett.* **42**, 399 (1979)], equivalent to a clay flux of approximately 1 mg $m^{-2}$ $day^{-1}$, which were far smaller than the estimated flux in the shallowest trap.
9. G. R. Heath, T. C. Moore, G. L. Robert, *J. Geol.* **82**, 145 (1974); S. Honjo, S. J. Manganini, L. J. Poppe, *Mar. Geol.*, in press.
10. The clay constituent in all samples was nearly consistent throughout the year at all depths: 60 percent smectite (95 percent beidellite), 11 percent kaolinite, 11 percent chlorite, 9 percent quartz, and 9 percent feldspar. Illite, a highland clay, was present in trace amounts in all samples.
11. I thank K. W. Doherty and J. F. Connell who aided in developing the time-series device for the Parflux sediment trap. I thank S. J. Manganini and L. J. Poppe who carried out laboratory analyses of the trap samples and J. J. Cole, R. C. Thunell, W. B. Curry, and E. Evans who reviewed the manuscript. This research was supported by NSF grant OCE 8125429. Woods Hole Contribution No. 5006.

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