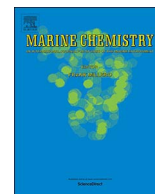




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Size-fractionated distributions of suspended particle concentration and major phase composition from the U.S. GEOTRACES Eastern Pacific Zonal Transect (GP16)

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ABSTRACT

Marine particles play key roles in the cycling of most elements in the ocean. Here we present full water column sections of size-fractionated (1–51 μm; > 51 μm) concentrations of suspended particulate matter (SPM) and major particle phase composition, including particulate organic matter (POM), calcium carbonate (CaCO₃), opal, lithogenic particles, and iron and manganese (oxyhydr)oxides, as well as the Redfield (C:N:P) stoichiometry of particles, from the U.S. GEOTRACES GP16 Eastern Pacific Zonal Transect (EPZT). The GP16 cruise sampled the oxygen deficient waters of the productive eastern upwelling Peru margin westward to Tahiti through the East Pacific Rise (EPR) hydrothermal plume around 12°S in October–December 2013. In this region of relatively low mineral dust deposition, the sum of POM and CaCO₃ concentrations accounted for > 80% of small size fraction (SSF) SPM for most of the section. Some exceptions to this include the southern EPR hydrothermal plume, where iron oxyhydroxides accounted for almost 60% of SSF SPM, and the coastal upwelling zone, where opal and lithogenic particles accounted for ~50% of SSF SPM. We discuss possible mechanisms to explain a large sediment resuspension feature on the deep Peru continental slope. Large size fraction (LSF) particles generally had relatively higher contributions of opal and lower contributions of POM compared to SSF particles, reflecting an unusually high size partitioning of opal to the LSF. Distributions of CaCO₃ and other phases were more strongly controlled by particle dynamics than by dissolution. Our particle phase data are consistent with a conceptual model where particle production, aggregation, and disaggregation processes dominate in the euphotic, 100–300 m, and 300–500 m depth zones, respectively. Our direct measurements of particle composition showed 1) euphotic zone C vs P relationships (SSF: 48 ± 13; LSF: 65 ± 14) that were significantly lower than canonical Redfield values (~106), but that were consistent with previously published large scale inverse and box model estimates of exported C:P for this region, and 2) PIC:POC ratios (LSF: 0.088) that were remarkably similar to estimated rain ratios from a biogeochemical-transport box model of alkalinity and nitrate in the low latitude Pacific.

1. Introduction

GEOTRACES is an international program to study the global marine biogeochemical cycles of trace elements and their isotopes (TEIs). The program's guiding mission is to “identify processes and quantify fluxes that control the distributions of key TEIs in the ocean” (GEOTRACES, 2006). Particles are a key parameter for the GEOTRACES program because of their role as sources, sinks, and in the internal cycling of so

many TEIs (GEOTRACES, 2006; Jeandel et al., 2015).

Particles in the ocean can be supplied externally to the ocean system, such as through atmospheric dust deposition, river input, sedimentary resuspension, and hydrothermal input, or generated internally to the ocean system, through biological production of particulate organic matter (POM) and biominerals such as calcium carbonate (CaCO₃) and opal or authigenic precipitation of minerals (Jeandel et al., 2015).

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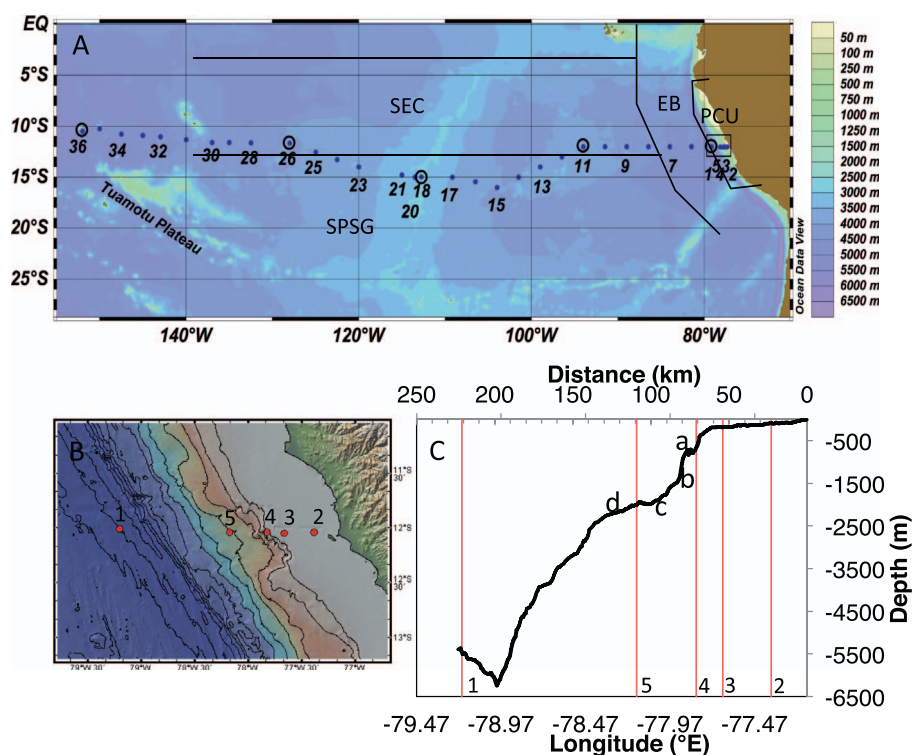


Fig. 1. (A) Map of the EPZT GP16 cruise track showing all stations (blue dots). Full stations sampled by in-situ pumps are numbered. Super stations with higher depth resolution are circled. Four biogeographic regions defined by Pennington et al. (2006) indicated: PCU = Peru Coastal Upwelling; EB = Eastern Boundary; SEC = South Equatorial Current; SPSG = South Pacific Subtropical Gyre. (B) Zoom in view of Stations 1–5 in the Peru coastal upwelling region indicated by rectangle in A, showing 500 m bathymetric contours. (C) Bathymetric profile along 12°S from coast to Station 1. Thin red vertical lines indicate locations of Stations shown in panel B. Bottom slope between a-b is 119 m/km; between b-c is 34 m/km; between c-d is 11 m/km. Bathymetric data in B, C from GMRT. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Because particles are defined operationally as anything that can be captured on a filter (McDonnell et al., 2015), they comprise a wide range of compositions, from the biogenic components (e.g., POM, CaCO_3 , and opal—Lam et al., 2015b) to the abiotic components (e.g., lithogenic material, authigenic minerals). The relative contributions of these components depend on the proximity to and strength of the most important external or internal sources, and the strength of the particle removal terms, which are dominated by particle dynamics processes that lead to particle aggregation, sinking, disaggregation, remineralization and dissolution.

Particle concentration is thought to exert a major control on the scavenging of particle-reactive trace elements. The number of available sites on particle surfaces for binding TEIs should scale with the concentration of particles, and also be a function of particle composition, since some particle phases (e.g., oxyhydroxides) have one to two orders of magnitude higher specific surface areas than others (e.g., clays—Keil et al., 1994; Toner et al., 2005). The types of binding sites should also influence net adsorption. Again, particle composition should be expected to be important, as particle phases can vary in their surface charge (e.g., Fe oxyhydroxides are neutral to slightly positively charged, whereas Mn oxides are negatively charged), which would influence electrostatic interactions (Hein et al., 2013; Moon and Peacock, 2013; Peacock and Sherman, 2007), and in their surface functional groups (e.g., of different types of particulate organic matter), which would influence surface complexation of TEIs (Balistrieri et al., 1981; Quigley et al., 2002; Quiroz et al., 2006).

Indeed, laboratory experiments show several orders of magnitude range in the affinity of particle-reactive radionuclides such as thorium and protactinium to particles of varying compositions (Geibert and Usbeck, 2004; Guo et al., 2002), and this has been corroborated in field experiments examining the partition coefficients of particle-reactive radionuclides to sediments (Balistrieri and Murray, 1986; Kretschmer et al., 2011), sinking particles from sediment traps (Chase et al., 2002; Roy-Barman et al., 2005; Roy-Barman et al., 2009; Scholten et al., 2005), and suspended particles collected by in-situ filtration (Hayes et al., 2015). There is not as yet consensus on the most important particle phases for controlling scavenging, however, and this may be

due in part to the fact that correlations between partition coefficients and sinking particles collected by sediment traps conflate the two key steps involved in scavenging: adsorption onto particles, and the subsequent removal of particles by sinking (Jeandel et al., 2015). Only recently have field-based scavenging studies been conducted on suspended particles in the ocean (Hayes et al., 2015; Lamborg et al., 2016), largely because there have been very few concurrent measurements of dissolved and particulate TEI concentrations and suspended particle concentration and composition until the GEOTRACES program.

There are many other reasons to be interested in particle composition. For example, the ratio of CaCO_3 to particulate organic carbon (POC) in exported particles, also known as the rain ratio, is an important determinant of the role that the biological pump plays in drawing down atmospheric CO_2 (Archer et al., 2000; Sarmiento et al., 2002). Spatial variations in the “Redfield” stoichiometry (C:N:P ratio) of exported particles may affect our estimates of global carbon export (Teng et al., 2014) and the coupling of the cycles of nutrients, oxygen, and carbon (DeVries and Deutsch, 2014).

Here, we report a full-depth zonal section of size-fractionated particle concentration and composition from the U.S. GEOTRACES GP16 Eastern Pacific Zonal Transect (EPZT) cruise that took place October–December 2013. This is only the second full depth section of this kind. This paper discusses the main features in the distribution of the concentration and major phase composition (particulate organic matter, CaCO_3 , opal, lithogenic particles, and Fe and Mn (oxyhydr) oxides) and Redfield (C:N:P) stoichiometry of size-fractionated particles collected by in-situ filtration. A companion paper (Lee et al., this issue) reports on the minor and trace metal concentrations and size distributions.

2. Methods

2.1. Cruise track and hydrography

The U.S. GEOTRACES Eastern Pacific Zonal Transect (EPZT; GP16) cruise sailed from 25 October to 20 December 2013 on the RV Thomas G. Thompson (TT-303) from Manta, Ecuador to Papeete, French

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