

**NSF OCE-1736612: Collaborative Research: Pb-210 and Po-210 as tracers of scavenging and export:  
GEOTRACES Pacific Meridional Transect**

**Award Amount: \$244,647**

**Award Time Period: 9/1/2017-8/31/2020**

## **1.0 Introduction**

The mission of the International GEOTRACES Program is “to identify processes and quantify fluxes that control the distributions of key trace elements and isotopes (TEIs) in the ocean, and to establish the sensitivity of these distributions to changing environmental conditions.” These chemical species play important roles in the ocean as nutrients, tracers of current and past oceanographic processes, and as contaminants from human activity. Their biogeochemical cycling has direct implications for research in such diverse areas as the carbon cycle, climate change, and ocean ecosystems. GEOTRACES was created to allow a comprehensive, coordinated study of these trace elements and isotopes.

This study will use the radionuclide pair—  $^{210}\text{Pb}$  and its grand-daughter,  $^{210}\text{Po}$ — to provide important biogeochemical rate information pertinent to the TEIs that will be measured during the US GEOTRACES meridional transect in the Pacific from Alaska to Tahiti in 2018. Many processes in the ocean cannot be directly observed and, as such, tracers are used to provide important constraints on their rates and pathways.  $^{210}\text{Po}$  (half-life = 138 d) and  $^{210}\text{Pb}$  (half-life = 22.3 y) decay on timescales that are useful to study atmospheric deposition, scavenging, and export of particulate organic carbon (POC) from the photic zone, to name a few. This research will build on a database of Po/Pb distributions in the world ocean (and the Pacific Ocean, in particular) obtained through programs such as GEOSECS and GEOTRACES, as well as independent studies, and will address key tasks formulated within the GEOTRACES Science Plan.

## **2.0 Background**

$^{210}\text{Pb}$  and its granddaughter,  $^{210}\text{Po}$ , are members of the  $^{238}\text{U}$  decay series, and both are considered particle-reactive in their respective marine geochemistries. In the oceanic water column,  $^{210}\text{Pb}$  is produced ultimately from decay of its grandparent,  $^{226}\text{Ra}$ .  $^{210}\text{Pb}$  is also added to the surface ocean from the atmosphere, where it is produced by the decay of  $^{222}\text{Rn}$  that has emanated from continental rocks and soils. The  $^{222}\text{Rn}$  flux from continental rocks and soils is much greater than that from the surface ocean, and consequently, the  $^{210}\text{Pb}$  flux to the Earth's surface is generally higher over the continents than over the ocean. In the North Pacific, the atmospheric flux is about 6% of the production from  $^{226}\text{Ra}$  in the water column (Cochran et al., 1990).

Early results documenting distributions of  $^{210}\text{Po}$  and  $^{210}\text{Pb}$  in the oceans (Craig et al., 1973; Bacon et al., 1976, 1988; Thomson and Turekian, 1976; Nozaki et al., 1976; Nozaki and Tsunogai, 1976; Somayajulu and Craig, 1976; Spencer et al., 1981; Cochran et al., 1983; Chung and Craig, 1983; see also Cochran, 1992) showed that  $^{210}\text{Pb}$  was scavenged relative to equilibrium with its grandparent  $^{226}\text{Ra}$  and that  $^{210}\text{Po}$  was more rapidly removed from surface waters than  $^{210}\text{Pb}$  ( $^{210}\text{Po}/^{210}\text{Pb}$  in solution < 1). At depth, however,  $^{210}\text{Po}$  can be released from sinking particles such that the activity ratio of  $^{210}\text{Po}/^{210}\text{Pb}$  in solution is >1 (Cochran et al. 1983; Bacon et al., 1988; Cochran, 1992). Excess  $^{210}\text{Po}$  has also been observed in surface waters within upwelled coastal filaments as the products of particle respiration (e.g.  $\text{NO}_3$ ,  $\text{NO}_2$ ) are transported upward by the upwelling process (Kadko, 1993a).

An important aspect of the behavior of Po that helps explain these observations of  $^{210}\text{Po}/^{210}\text{Pb}$  disequilibrium is its assimilation into cells, possibly as an analog of sulfur (Fisher et al. 1983; 1987). Stewart and Fisher (2003a) showed that Po uptake in marine phytoplankton cultured in the laboratory is explained by both a surface bound fraction and a cellular fraction associated with protein. Such behavior helps account for observed links between chlorophyll a (denoting living organic matter), productivity, POC concentration and the rate of Po scavenging (Nozaki et al., 1997; 1998; Hong et al., 1999; Sarin et al., 1999; Choi et al., 2014). As well, if some of the Po taken up by phytoplankton is assimilated, it may be released as the organic matter decomposes during sinking. Thus Po may behave more like carbon than Th or Pb with respect to its scavenging on particulate organic matter and involvement in marine food webs. This aspect makes it a potentially powerful tracer of POC export, in a fashion similar to the use of  $^{234}\text{Th}$  as a POC flux proxy.

## 2.1 The GEOTRACES Pacific Meridional Transect

The proposed GEOTRACES Pacific Meridional Transect along 152°W (hereafter referred to as the “152W transect”) from Tahiti to Alaska, Fall, 2018 (Fig. 1) will cross numerous biogeochemical “provinces” in which  $^{210}\text{Po}$  and  $^{210}\text{Pb}$  comprise powerful process tracers.

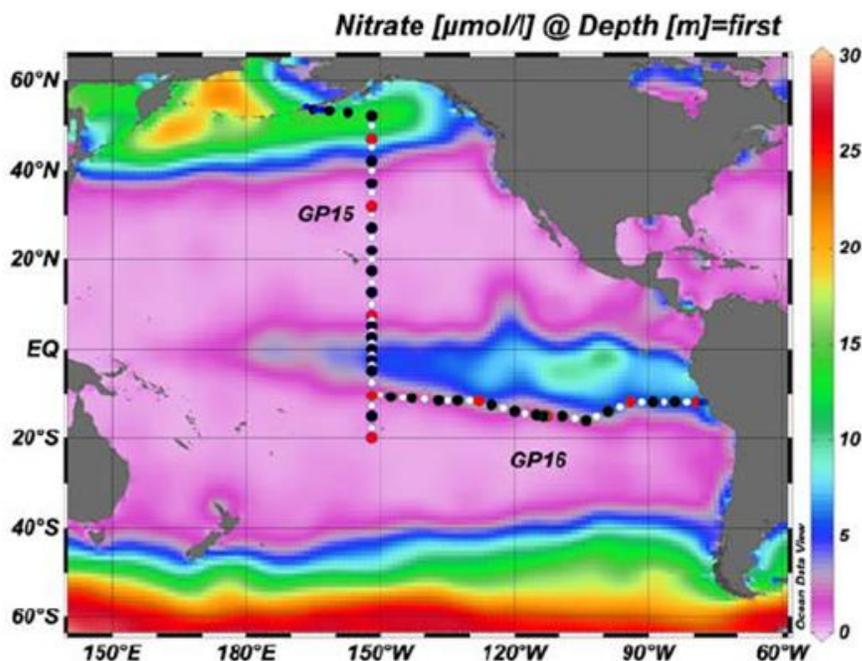


Fig. 1: Cruise track for the 2018 Meridional Pacific Transect (GP15) overlaid on annual average surface nitrate concentrations ( $\mu\text{mol}/\text{kg}$ ) from the World Ocean Atlas 2013. Large black and red symbols indicate Full and Super stations, respectively (both full-depth stations), while small blue and white symbols show Slope and Demi stations, respectively (shallow stations). Stations from the 2013 GEOTRACES Eastern Pacific Zonal Transect (EPZT, GP16) are also shown.

Several characteristics of the transect hold particular relevance to the work proposed here:

- 1) There is a significant meridional gradient in the supply of dust and associated trace elements derived from the deserts of East Asia, leading to elevated deposition in the northern basin (Jickells, et al, 2005; Buck et al., 2013)

2) There are gradients in biological productivity and export production that influence the internal cycling and removal of trace elements. The transect crosses the relatively productive region of the eastern subarctic Pacific, including the high productivity Subarctic Frontal Zone at 32°N, the oligotrophic North Pacific subtropical gyre, the productive equatorial region and the highly oligotrophic South Pacific subtropical gyre.

3) At depth, the eastward flowing Equatorial Countercurrent will be sampled. This current has the potential to transport trace elements and their isotopes (TEIs) into the oxygen minimum zones of the eastern Pacific. Pacific Deep Water, the terminus of the ocean conveyor belt and the “oldest” radiocarbon-dated water in the ocean, will also be sampled.

4) The transect will intersect hydrothermal plumes extending from the Juan de Fuca Ridge (35°N), Loihi Sea Mount (20°N) and the E. Pacific Rise (9°N, 15°S), affording the opportunity to investigate of the role of hydrothermal plumes as a sink for particle-reactive trace elements via scavenging processes (e.g. German et al., 1991; Kadko, 1993b).

5) At its northern end, detailed sampling of the shelf/slope in the interior Gulf of Alaska will permit the evaluation of this area as an advective source (e.g. Fe) and sink (e.g.  $^{210}\text{Pb}$ ) of TEIs.

**Specific goals:**

- Utilize  $^{210}\text{Pb}$  and the  $^{7}\text{Be}/^{210}\text{Pb}$  ratio as an atmospheric source and flux tracer
- Utilize  $^{210}\text{Pb}$  as a tracer of scavenging rates of TEIs
- Study the effect of hydrothermal processes on water column  $^{210}\text{Pb}$  distributions
- Utilize  $^{210}\text{Po}$  as a proxy for POC export in areas of high and low POC export