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Hydrothermal versus active margin sediment supply to the eastern equatorial Pacific over the past 23 million years traced by radiogenic Pb isotopes: Paleoceanographic and paleoclimatic implications

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Abstract

We investigated the evolution of the Pb isotopic composition of bulk sediments on the Cocos Plate in sedimentary successions of Deep Sea Drilling Project (DSDP) Site 495 and Ocean Drilling Program/Integrated Ocean Drilling Program (ODP/IODP) Site 1256 over the past 23 million years of depositional history. Our study addresses the relationship of the sediment Pb isotope record to plate tectonics, weathering inputs, and paleoceanography. It is the first effort to characterize the Pb isotopic evolution of eastern equatorial Pacific sedimentation covering the entire tectonic pathway of the Cocos Plate from its formation at the East Pacific Rise to its arrival at the Central American subduction zone. The Sites 495 and 1256 bulk sediment Pb isotope records are fully consistent over time despite distinct differences between the type of sediment deposited at both locations. A systematic and continuous trend from ~23 to ~6–4 Ma toward more radiogenic Pb isotopic compositions, e.g., $^{206}Pb/^{204}Pb$ ratios increase from 18.29 to 18.81, reflects a decrease in the contribution of hydrothermal particles from the East Pacific Rise and an increase in the predominantly eolian contribution of mixed weathering products from the continental arcs of the Northern and south Central Andes as well as from southern Mexico. Surprisingly, both the Pb isotopic composition of the detrital fraction and that of past seawater indicate that inputs from nearby Central America and the Galápagos Archipelago did not significantly contribute to the sediments of our core locations but were overwhelmed by other sediment sources. A systematic change to less radiogenic Pb isotope ratios in sediments younger than ~4–3 Ma, reaching present-day $^{206}Pb/^{204}Pb$ values near 18.70, reflects a reduction of the continental input from the South Central Volcanic Zone of the Andean Arc and increased contributions from southern Mexican igneous complexes. This isotopic trend reversal took place as a consequence of changes in atmospheric circulation, when the studied sites crossed the Intertropical Convergence Zone due to tectonic drift and concurrent climate cooling. Eolian transport has played a major role in the supply of detrital material over the entire Neogene and Quaternary. The delivery of hydrothermal Pb originating from the East Pacific Rise to the easternmost tropical Pacific has been a persistent feature that is attributed to a remarkably stable central and eastern Pacific deep-water flow pattern over millions of years. Thus, deep ocean circulation did not change significantly either (1) as a consequence of an Early Miocene closure of the deep gateway between the Caribbean and eastern Central Pacific or because (2) a Late Miocene to Pliocene closure of the Central American Seaway had no impact at all.

Keywords: IODP Site 1256; DSDP Site 495; Marine sediments; Pb isotopes; Cocos Plate; Eastern equatorial Pacific

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1. INTRODUCTION

Lead (Pb) isotopes have served as a powerful tool for tracking the source regions of oceanic water masses (e.g., O'Nions et al., 1978; von Blanckenburg et al., 1996; Abouchami et al., 1997; Frank et al., 1999; van de Flierdt et al., 2004a,b; Ling et al., 2005; Haley et al., 2008) and of detrital sediments (e.g., Chow and Patterson, 1962; Jones et al., 2000; Pettke et al., 2000, 2002; Godfrey, 2002; Stancin et al., 2006; Xie and Marcantonio, 2012; Basak and Martin, 2013; Pichat et al., 2014; Wilson et al., 2015) on different time scales. The importance of dissolved Pb isotopes as an oceanographic tracer for continental inputs arises from the low mean deep-water oceanic residence time of dissolved Pb of ~50 (Atlantic) to ~200–400 (Pacific) years (Schaule and Patterson, 1981; von Blanckenburg and Igel, 1999), being considerably shorter than the global ocean mixing time of ~1500 years (e.g., Broecker et al., 1982). Since there are three radiogenic Pb isotopes, they allow detailed reconstructions of complex mixing relationships between different isotopic source end-members within the same isotopic system (cf. Frank, 2002; Goldstein and Hemming, 2003). Variations in the Pb isotopic composition of different phases of marine sediments thus provide an important archive for reconstructing both tectonically and climatically driven changes in sediment provenance and in the signatures of water masses transporting the particulate or dissolved Pb through time.

In the eastern equatorial Pacific Ocean (EEP), possible sedimentary source materials include (1) tephras released from the Galápagos Hotspot and the Mexican, Central American, and Andean subduction zone volcanoes, (2) particulate matter originating from expelled hydrothermal fluids associated with areas of active submarine volcanism at the East Pacific Rise and at the Galápagos (or Cocos-Nazca) spreading centers, as well as Galápagos volcanoes, and (3) detrital (riverine and airborne) inputs derived from weathering and erosion of the surrounding active continental margins (Fig. 1). Changes in the proportions of these contributing sources bear important information on the climatic and tectonic evolution of the EEP, which can be reconstructed from the detrital Pb isotopic compositions of EEP sediments. To date, only few such studies have been carried out. Following the pioneering work of Nakai et al. (1993), who investigated Sr–Nd isotopic compositions of the eolian detrital fraction of Late Pleistocene EEP sediments to constrain its source areas, Jones et al. (2000) concluded from detrital Pb isotope distributions that dust supply of South American origin

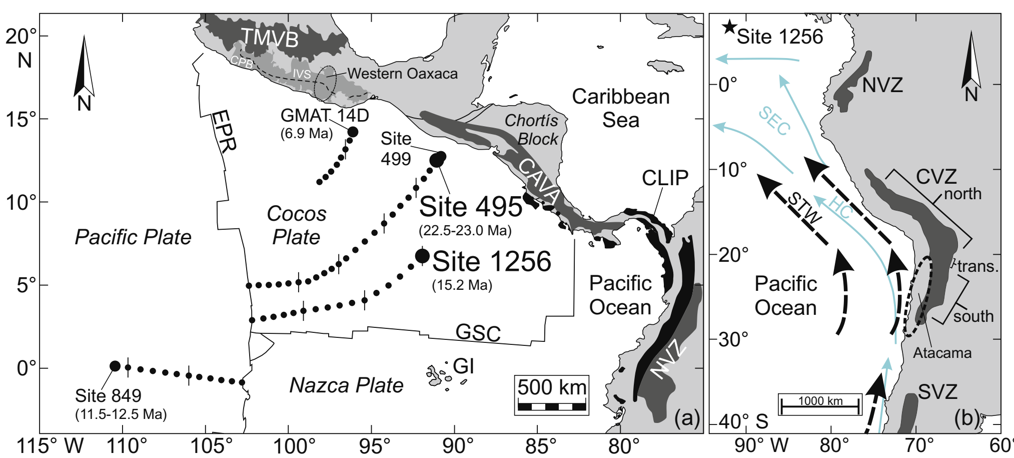

Fig. 1. (a) Map of the eastern equatorial Pacific and adjacent continental areas, showing the locations of the studied ocean drilling sites 495 and 1256 together with other oceanic locations referred to in the text (Fe–Mn crust GMAT 14D; drilling sites 499, 849). Indicated oceanic crustal ages of drilling site locations are based on magnetic lineations (Sites 495, 499: von Huene et al., 1982; Geldmacher et al., 2013; Sites 849, 1256: Wilson, 1996) according to the geomagnetic polarity time scale of Cande and Kent (1995). The age of Fe–Mn crust GMAT 14D is derived from Frank et al. (1999). Reconstructed tectonic tracks were calculated with the software GPlates (http://www.gplates.org; version 1.1.1). Small dots along the tracks mark 1 Ma and small ticks label 5 Ma increments. Spreading ridges: EPR = East Pacific Rise, GSC = Galápagos Spreading Center (Cocos-Nazca Spreading Center). Other oceanic/continental geological entities: CAVA = Central American Volcanic Arc, CLIP = Caribbean Large Igneous Province (uplifted parts), CPB = Coastal Plutonic Belt, GI = Galápagos Islands, IVS = Inland Volcanic Sequences, NVZ = Northern (Andean) Volcanic Zone, TMVB = Trans-Mexican Volcanic Belt. Simplified boundary between Cenozoic IVS and CPB in southern Mexico modified from Morán-Zenteno et al. (1999). The dashed ellipse marks the western Oaxaca area studied by Martiny et al. (2000) who produced Pb isotope data used for comparison with the data set of the present study. Chortís Block tectonic boundaries after Rogers et al. (2007). (b) Map of the easternmost tropical and southeastern Pacific and adjacent western part of South America [adapted from Hart and Miller (2006), including oceanic circulation data from Kessler (2006)], depicting major present-day ocean surface (turquoise arrows) and wind (dashed black arrows) currents affecting this area: HC = Humboldt Current, SEC = South Equatorial Current, STW = Southeast Trade Winds. In addition, major volcanic zones of the Andes including the Atacama Desert are displayed: NVZ = Northern Volcanic Zone, CVZ = Central Volcanic Zone (north, transitional (trans.), south; cf. Pichat et al., 2014), SVZ = Southern Volcanic Zone. Note that the Austral Volcanic Zone, being the southernmost Andean Arc segment, follows south of the SVZ (i.e., from 49° to 55°S), thus outside the shown map. Site 1256 location is marked by a black star.