The seawater neodymium and lead isotope record of the final stages of Central American Seaway closure

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Therefore, it is critical to reconstruct not only the timing of final complete CAS closure but also the restriction of the seaway to deep and intermediate waters in order to test how CAS closure was linked to AMOC strength. Here we reconstruct seawater Nd and Pb isotope compositions in the eastern equatorial Pacific and the deep and intermediate Caribbean for a detailed investigation of the final stages of CAS closure, which may have been interrupted by intermittent reopenings as a result of either tectonics or ice volume changes [[illegible]., 2009;

2. Materials and Methods

2.1. Sample Sites and Hydrological Setting

Pliocene to early Pleistocene Nd isotope records were obtained from ODP Sites 998, 999, and 1000 in the Caribbean and ODP Site 1241 in the eastern equatorial Pacific (Figure 1). Core top samples from nearby locations were measured for calibration purposes (Table S1 and Figure S1 in the supporting information). ODP Site 999 (12°45′N, 78°44′W, 2828 m water depth) is located on Kogi Rise in the deep Colombian Basin [[illegible]., 1997] and ODP Site 998 (19°39′N, 82°56′W, 3180 m water depth) was drilled on the Cayman Rise between the Yucatan Basin and the Cayman Trough. Deep waters entering the Caribbean from the Atlantic must pass across the relatively shallow sills of the Antilles Island Arc, which reach a maximum depth of ~ 1900 m [[illegible]., 2002] and thus only allow inflow of Upper North Atlantic Deep Water (UNADW) today. Shallower ODP Site 1000 (16°33′N, 79°52′W, 916 m water depth) is well placed for recording changes at intermediate water depths in the Caribbean and is at present under the influence of Antarctic Intermediate Water (AAIW) [[illegible], 1964]. Pacific ODP Site 1241 is located on the northern slope of the Cocos Ridge in the Guatemala Basin (5°51′N, 86°24′W, 2027 m, [[illegible]., 2003]), bathed today in relatively oxygen-depleted waters characterized by low $\delta^{13}C$ signatures originating from mid-depths in the north Pacific [[illegible], 1998].

2.2. Age Models

We present data for the time interval 5.6 to 2.2 Ma, with a resolution of between 50 and 100 kyr, using age models established by [illegible] [1998], [illegible]. [2007], [illegible]. [2006, 2010], and [illegible] [2000]. The benthic foraminifer isotope records of Caribbean Sites 999 and 1000 have previously been correlated to Atlantic Site 925/926 and to the 1241 age model, thus allowing direct comparisons of paleoceanographic changes between these three sites [[illegible]., 2006].

2.3. Sample Preparation and Isotope Analysis

Fossil fi

Mixed planktonic foraminifera weighing 25 to 50 mg were crushed between two glass plates and

2010;

of detrital particles and the composition of other local rivers is necessary before firm conclusions can be drawn about the probable cause of offset between bulk leachate and foraminiferal ε_{Nd} signatures. There are no published seawater ε_{Nd} data for the Caribbean to date, but profiles in the western equatorial Atlantic [[illegible], 1987] and at Demerara Rise [[illegible]., 2014] show that the core of AAIW today has an ε_{Nd} signature between −11.2 and −10.1 prior to entering the Caribbean. A hydrogenetic ferromanganese crust layer from a water depth between 600 and 950 m water depth in the eastern Caribbean gave an ε_{Nd} value of −10.5 [[illegible]., 2006]. It is noted that these signatures are significantly less radiogenic than the composition of AAIW close to its source region in the Southern Ocean (ε_{Nd} between −8 and −9 ε_{Nd}) [[illegible]., 2009; [illegible]., 2012] due to mixing and dilution of AAIW with less radiogenic Atlantic water masses prior to entering the Caribbean basin. Near Site 1000, the average core top foraminiferal composition (ε_{Nd} = −10.7) but are presented and compared with the foraminifera data in the supporting information (Figure S2). In contrast, fish teeth and foraminiferal ε_{Nd} values are considered reliable, and we will therefore base our interpretations only on these data.

3.2. Pliocene Pb Isotope Evolution of the Eastern Equatorial Pacific and the Caribbean

The Pliocene seawater Pb isotope signatures obtained from the bulk sediment leachates at Site 1241 are more radiogenic than the deep Pacific as recorded by ferromanganese crust GMAT 14D [[illegible]., 1999] (Table S3a and Figure 4). Variations in the seawater Pb composition at Site 1241 were small (between 18.79 and 18.88 for $^{206}Pb/^{204}Pb$, between 15.62 and 15.64 for $^{207}Pb/^{204}Pb$, and between 38.66 and 38.78 for $^{208}Pb/^{204}$

from ~ 7 Ma onward [[illegible], 2009]

approached, but did not reach, the range of the unradiogenic intermediate depth core top compositions (-9.7 to -12.4 ε_{Nd}).

The Miocene-Pliocene record (Figure 5) shows that the majority of the change in deep Caribbean ε_{Nd} away from Pacific-like compositions had already taken place prior to about 7 Ma [[illegible], 2009] but that the trend toward less radiogenic ε_{Nd} signatures continued throughout the Pliocene. Leachate and detrital Pb isotope compositions (Figure 4) do not indicate that any significant change in weathering inputs during the Pliocene contributed to a change in the deep Caribbean seawater ε_{Nd} signal. The key question is therefore whether the ε_{Nd} records reflect the continued but decreasing influence of Pacific waters

., 2009; ., 2012] we argue that it is unlikely that the ε_{Nd} signature of AAIW was significantly less radiogenic than −9 at its source and that there is consequently no need to invoke any volumetrically important admixture of Pacific water to the deep Caribbean.

3.4.2. Residence Time of Nd and Exchange With the Margin Sediments

A change in the offset between incoming Atlantic seawater ε_{Nd} and the composition of seawater in the deep Caribbean is another potential factor contributing to the Pliocene ε_{Nd} trend. Despite the relatively long

3.4.3. Short-Term Nd Isotope Variability of Caribbean Intermediate and Deep Waters

Finally, the Pliocene Caribbean ε_{Nd} records also show variability on shorter timescales (Figure 4). Planktonic $\delta^{18}O$ records [[illegible]., 2001] and sea surface salinity reconstructions [[illegible], 2005; [illegible]., 2006, 2008; [illegible]., 2006] indicate that the CAS had shoaled to ~ 100 m by ~ 4.2 Ma. The intermediate water ε_{Nd} record from uncleaned planktonic foraminifera for Site 1000 is plotted together with the ice volume-corrected $\delta^{18}O$ gradient between

Overall, the observed Pliocene changes in Caribbean circulation related to the final closure of the CAS were smaller than during the Miocene between 12 and 7 Ma ago [[illegible], 2009], when the CAS closed for major deep water exchange.

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