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Dynamic carbonate sedimentation on the Northern Line Islands Ridge, Palmyra Basin

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ABSTRACT

The Line Islands Ridge (LIR), located south of the Hawaiian Islands between 7°N and 1°S, is one of the few large central Pacific regions shallower than the regional carbonate compensation depth. Thick sequences of carbonate sediments have accumulated around the LIR despite it being located in the sediment-starved central tropical Pacific. The LIR is an important source of carbonates to the surrounding region and deposition around the LIR has expanded the equatorial Pacific carbonate sediment tongue by about 5% of its total area. Furthermore, sediments on the ridge are potentially important paleoceanographic archives. A recent survey at the crest of the LIR finds evidence for high current activity, significant erosion, but overall net sediment deposition. Currents are strong enough to form sediment waves and lee drifts in the Palmyra Basin, at the northern terminus of the LIR. Sediments along the LIR are pelagic foraminiferal sands that are easily eroded and flow out into the surrounding abyssal plain in active submarine channel systems. As channels migrate, pelagic sediments fill in the abandoned channel arms. Despite significant sediment losses from the top of the ridge, 1.3 km of sediment has accumulated in the upper Palmyra Basin over basement formed 68 to 85 million years ago (Ma). Late Neogene erosion may be more extensive than earlier erosion cycles, in response to reduced sediment production as the Palmyra Basin exited the high productivity equatorial latitudes. Sediments with good stratigraphic order needed for paleoceanographic study are limited in this dynamic sedimentary environment, but can be found with proper survey.

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1. Regional setting

The Line Islands Ridge (LIR, Fig. 1) is one of the few large areas in the central Pacific that stands above the regional carbonate compensation depth of ~4800 m (Berger et al., 1976). Elevated topography associated with the LIR extends ~1000 km southeast from 7°N to ~1°S. The highest peaks of the LIR form the Line Island chain, from Kingman Reef to Kiritimati (Christmas) Island (Fig. 1). The width of the LIR above the 3000 m depth contour varies from ~200 km in the north to <100 km at its southern end.

Sediments on the LIR should prove to be an important archive to study Pleistocene glacial-interglacial changes in surface ocean conditions (Lynch-Stieglitz et al., 2015) as well as the Cenozoic evolution of the Pacific Ocean and circumpolar deep-water flow in the abyssal Pacific with additional scientific drilling. The high topography of the LIR provides a platform sufficiently shallow for carbonate records to exist on Cretaceous-age crust. The LIR also spans across the central Pacific equatorial region to provide transects needed to study the paleoceanographic evolution of the central Pacific.

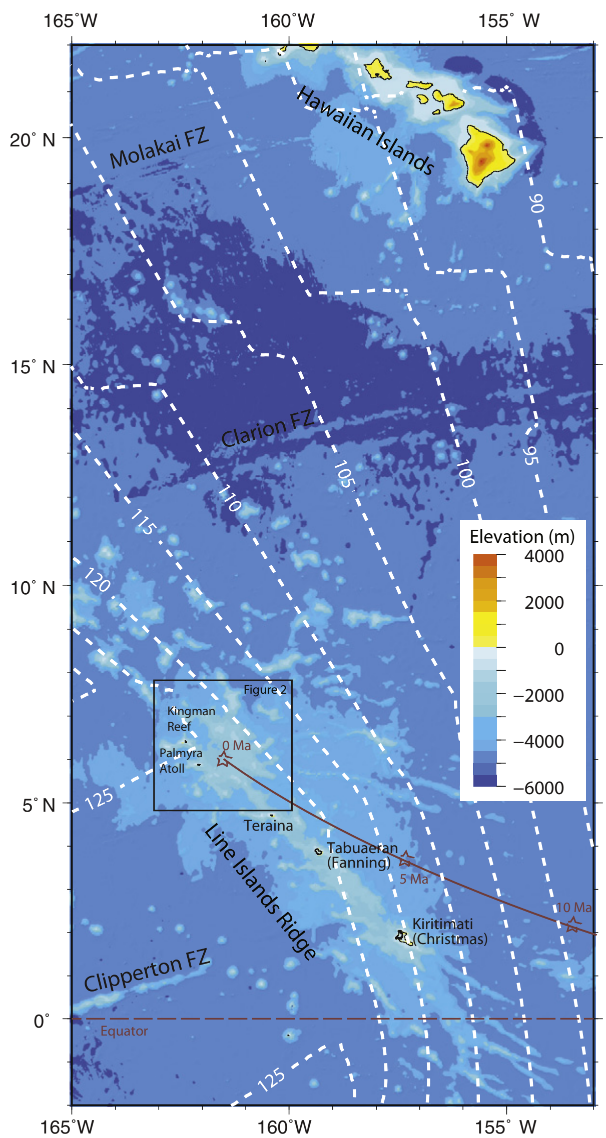

Fig. 1. Location of Line Islands Ridge with respect to the Hawaiian Islands. White dashed lines mark Pacific crustal ages in millions of years. Crustal ages are from Müller et al., 2008. The lack of offsets at fracture zones represents errors in the global data set. Red line and stars follow the tectonic backtrack of Palmyra Basin, on the northern Line Islands Ridge based on the fixed hotspot Pacific Plate model of Engebretson et al., 1985, spliced to Gripp and Gordon plate motions for 0–5 Ma. The location of Fig. 2 is shown by the box and is the location of MGL1208 survey area E.

Seismic stratigraphy around the LIR can potentially be used to understand changes in deep Pacific flow through changes in regional sediment deposition and formation of hiatus intervals. Circumpolar deep water (CPDW) now flows northward in the western Pacific, and splits to flow around the Hawaiian Islands (Talley, 2007). CPDW flowing east is blocked by the LIR, but CPDW eventually flows around it to the north between the LIR and Hawaii. A branch of bottom water returning from the eastern Pacific flows westward along the equator to the south of the LIR (Johnson and Toole, 1993).

1.1. Origin of LIR basement topography

Originally the LIR was thought to be a hotspot trace because the ridge extends in the general direction of Pacific Plate motion (Morgan, 1972). However dating of basalts along the chain failed to identify an age progression with distance (Schlanger et al., 1984). Much of the northern Ridge was built during two major periods of late Cretaceous volcanism, 81–86 Ma and 68–73 Ma (Davis et al., 2002) on ocean crust that was formed at about 120 Ma. Davis et al. (2002) proposed that LIR volcanism was associated with a broad upwarping of mantle in the South Pacific Superswell region (Larson, 1991; Adam and Bonneville, 2005). A more recent interpretation (Pockalny et al., 2015) suggests the LIR may result from two small overlapping hotspot traces, one associated with the Crough Hotspot and one with a possible hotspot near Pukapuka Ridge.

LIR topography is also different from that of Hawaii, where eruptions have been restricted to relatively few volcanic centers (Fig. 1) so that large but separate volcanic edifices are formed. Instead, the LIR is composed of multiple smaller volcanoes, spread over 1–2° of longitude across the general LIR trend. In the region between 5° and 7° N, the LIR bathymetry swells to form the largest region of shallow bathymetry in the chain (Fig. 2). The high topography consists of two bounding basaltic ridges to the southwest and northeast with a basin in the center filled with about 1.3 km of sediment. We refer to the northeastern ridge as Schlanger Ridge, the southwestern ridge as Kingman Ridge, and the basin between them as Palmyra Basin.

Kingman Ridge links 3 seamounts with relatively deep saddles between them. Two of the three seamounts also reach the sea surface to form Kingman Reef and Palmyra Atoll. Schlanger Ridge, in contrast, is more massive and connected, but the crest of Schlanger Ridge is about 1000 m below the sea surface. To the south, Palmyra Basin abuts against another southeast trending basement ridge that we call Langseth Ridge. Langseth Ridge is the southeast terminus of Palmyra basin (Fig. 2). The seamount that rises to form Kingman Reef has been dated to 70 Ma by ^{40}Ar—^{39}Ar total fusion dating, (Davis et al., 2002), while a basalt from a dredge from Schlanger Ridge was dated at 76 Ma, also using the ^{40}Ar—^{39}Ar total fusion method (Dredge 123D; Schlanger et al., 1984).

1.2. Sediments surrounding the LIR

The LIR is apparently a source of sediments to the surrounding sea floor (Fig. 3; Divins, 2003; updated in Whittaker et al., 2013). The sediment deposits around the LIR are all much thicker than typical pelagic deposits on Cretaceous seafloor in the Pacific. The sediment apron surrounding the LIR is a major pelagic sediment accumulation within the tropical Pacific comparable to the thickness of sediments at the crest of the eastern equatorial Pacific sediment bulge (~600 m at its crest; Hays et al., 1969; van Andel et al., 1975; Mitchell and Lyle, 2005).

Typical sediments to the north of the Clipperton Fracture Zone (FZ) are thin, ~150–250 m (van Andel et al., 1975; Lyle and Wilson, 2006; Pälike et al., 2010) because the ocean floor was formed in the early Cenozoic or late Cretaceous when the CCD was shallow (Arthur et al., 1985; Pälike et al., 2012). Consequently, carbonates typically were