Depositional Sequences and Relative Sea-Level Change in Jamaica Determined by Biostratigraphic Data*

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Abstract

Jamaica and its offshore basins are sparsely explored: only two wells have been drilled offshore and nine wells onshore, along with several shallow boreholes, and oil or gas shows have been seen in 10 of the 11 wells. Jamaica has a broad stratigraphic framework consisting of Cretaceous shales representing potential source rocks, and rudist limestones with reservoir potential. The Cretaceous succession is overlain by Paleogene carbonate and siliciclastic units which have both source and reservoir potential. The Middle Eocene Litchfield Formation is recognised as the main Cenozoic source rock, with potential reservoirs in the overlying Chapelton Formation and younger rocks. This data-rich study comprises new analyses of over 800 outcrop and well/borehole samples. New biostratigraphic and sedimentological data have enabled revision and updating of the sequence stratigraphic framework of Jamaica and the tie of depositional cycles to third-order sequences of Hardenbol et al. (1998), recalibrated to the 2012 geologic time scale (Gradstein et al., 2012).

Biostratigraphic analysis reveals several major unconformities. These are related to major tectonic (predominantly collisional) events that occurred during the assembly of the various terranes of the Nicaragua Rise. The environmental preferences of organisms identified during the biostratigraphic analyses permit the construction of a relative sea-level curve for the island of Jamaica (Figure 1). This curve reveals several newly identified transgressive-regressive (T-R) depositional cycles in the stratigraphy (Figure 1). Maximum transgressive and regressive inflections in the relative sea-level curve are associated with third-order sequences (Figure 1). T-R cycles are identified within the Early Cretaceous (EKTR1), Coniacian-Santonian (STR1), Campanian (CTR1), Maastrichtian (MTR1, MTR2), Paleocene-Early Eocene (PETR1), Early to Middle Eocene age Yellow Limestone Group (YTR1, YTR2, YTR3), and Late Eocene to Miocene age White Limestone Group (WTR1). Transgressions and regressions that are recorded within the Yellow Limestone Group represent changes in relative sea-level of only several tens of metres (Figure 1). Application of this new relative sea-level curve has enhanced the identification of potential source, reservoir, and seal units within the petroleum systems of Jamaica (Figure 1).

Discussion

The island of Jamaica and the region of the northern Nicaragua Rise are described to have been part of a continuous carbonate 'megabank' during the Paleogene (Droxler et al., 1991; Droxler et al., 1993; Sigurdsson et al., 1997; Mutti et al., 2005). Due to the absence of Paleogene reef-building organisms along the 'megabank' depositional settings are described using carbonate ramp terminology, defined by Burchette and Wright (1992). Eight depositional sub-environments within an overall carbonate ramp setting are identified by this study based on palaeontological and microfacies evidence: terrestrial, paralic, proximal inner ramp, distal inner ramp, shoal, middle ramp, outer ramp, and basinal (Figure 2). During the time interval investigated by this study, Jamaica remained within the tropics (<23.5° latitude). Consequently, the climate of Jamaica is dominated by tropical environments, including terrestrial settings with high rates of fluvial discharge and large volumes of siliciclastic run-off into offshore areas. Palynological evidence suggests mangroves were common in marginal marine settings, and where there were favourable environmental conditions micropalaeontological evidence suggests larger benthic foraminifera flourished and carbonate accumulation rates were high.

NE-SW directed extension of the Nicaragua Rise during the Middle to Late Eocene, possibly driven by sinistral strike-slip movement between the Caribbean and North American plates (Mitchell, 2003), caused rapid subsidence resulting in the transgressive events recorded within the depositional sequences of the Yellow Limestone Group (Figure 1). This extension formed structures which have a present-day NW-SE trend (Figure 3). The NW-SE trending structures form a series of horsts, which are onlapped by younger strata (Figure 3), and grabens. Horsts are represented by the Hanover and Clarendon Blocks, and offshore Pedro Bank. Whereas grabens are represented by the Montpelier-Newmarket and Wagwater Troughs which extend offshore and form sedimentary basins (e.g. the Walton and Blossom Basins).

During the Eocene a series of NW-SE trending horsts formed emergent palaeohighs that were fringed by paralic environments within a broader inner ramp setting, punctuated by frequent shoals (Figure 4). In the Pedro Bank, tilted fault blocks created WNW-ESE oriented terrestrial palaeohighs, which deepened on all sides to middle ramp environments, creating a middle ramp bridge between Pedro Bank and Jamaica, deepening to basinal conditions to the southwest (Figure 4). Paralic settings, including mangroves, fringing terrestrial palaeohighs were responsible for the deposition of the Litchfield Formation. Outboard of this marginal marine environment, inner ramp and shoal settings were responsible for the deposition of the Chapelton and Healthy Hill Formations, respectively (Figure 2). Formations deposited in these relatively deeper water environments transgressed over more proximal settings during the flooding of the palaeohighs associated with the transgressive phase of the YTR2 sequence (Figure 1 and Figure 2).

In the petroleum systems of Jamaica; source, reservoir, and seal units were deposited at different stages of the Jamaican relative sea-level cycle (Figure 1). Many potential source rocks in Jamaica are shown to be associated with periods of low relative sea-level. High quality source rocks of the Middle Eocene age Litchfield Formation were deposited in a paralic setting at the base of the second transgressive sequence (YTR2) identified in the Yellow Limestone Group (Figure 1). Many reservoir units, particularly within the Yellow Limestone Group, are interpreted to have been deposited during periods of transgression whereby source rocks deposited in proximal environments are replaced laterally and vertically by coarser siliciclastic sediments or porous shoal limestones. Regionally extensive stratigraphic seals are emplaced at the peak transgressive inflection of the relative sea-level curve as fine-grained, low permeability units deposited in deep-water settings (Figure 1).

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Figure 1. Relative sea-level curve of Jamaica generated by this study compared with published global mean sea-level curves. Ten unconformity-bounded transgressive-regressive (T-R) cycles that record one complete cycle of relative sea-level rise and fall are identified and named as depositional sequences by this study. Maximum transgressive and regressive inflections of the relative sea-level curve correlate with global third-order sequences. Source rocks are predominantly deposited during periods of low relative sea-level, with reservoirs and seals emplaced during subsequent transgression.
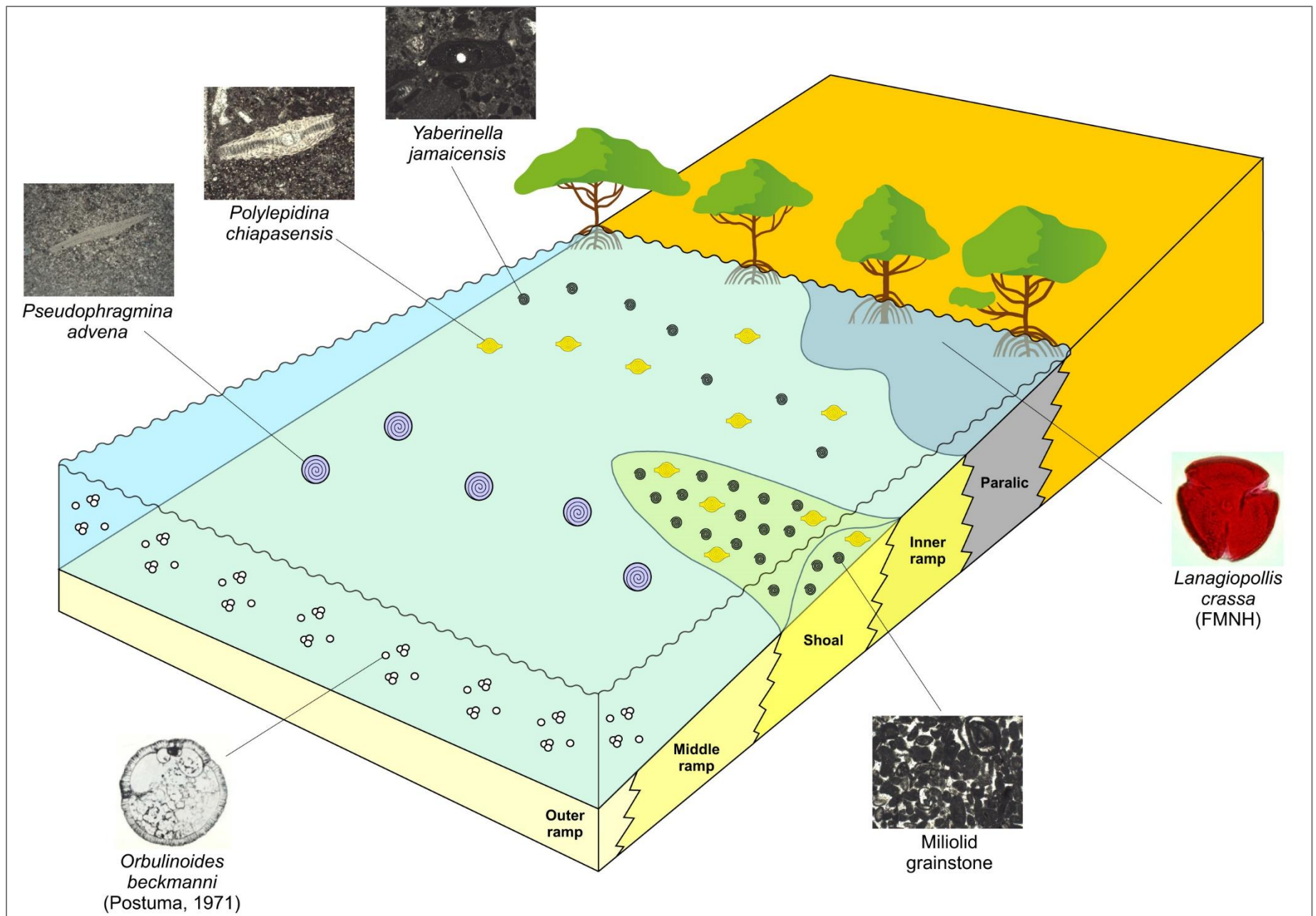
Figure 2. Conceptual model for the deposition of the second Yellow Limestone Group sequence (YTR2) displaying key facies and taxa found within distinct sub-environments (FMNH – Florida Museum of Natural History).
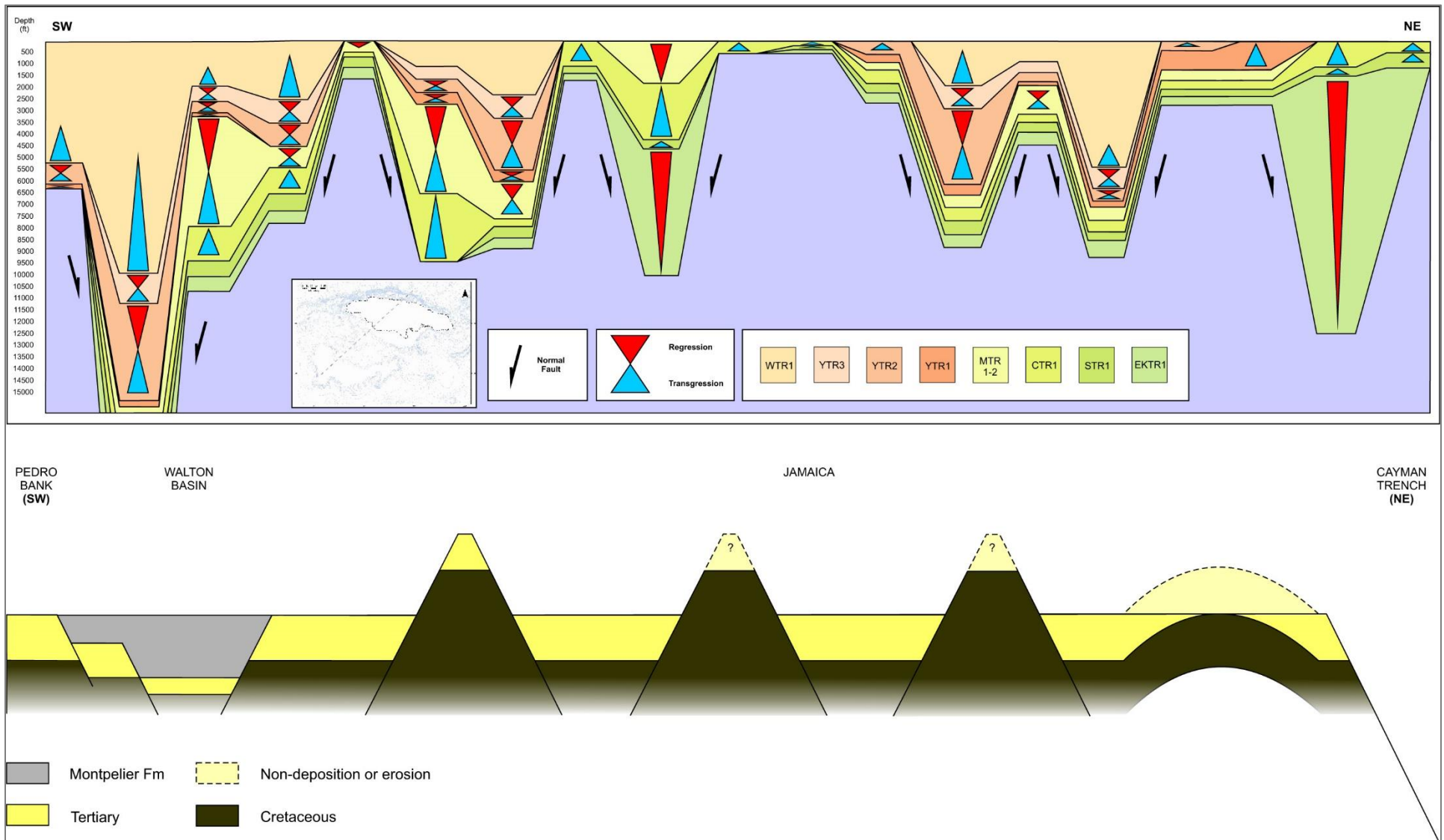
Figure 3. Top - Correlation of Jamaican depositional sequences across a NE-SW trend, displaying pinchouts of strata that onlap horst structures. Bottom – Simplified NE-SW oriented structural cross section of Jamaica during the Paleogene, displaying onshore horsts and grabens and offshore downthrown tilted fault blocks (modified from Benford, 2012).
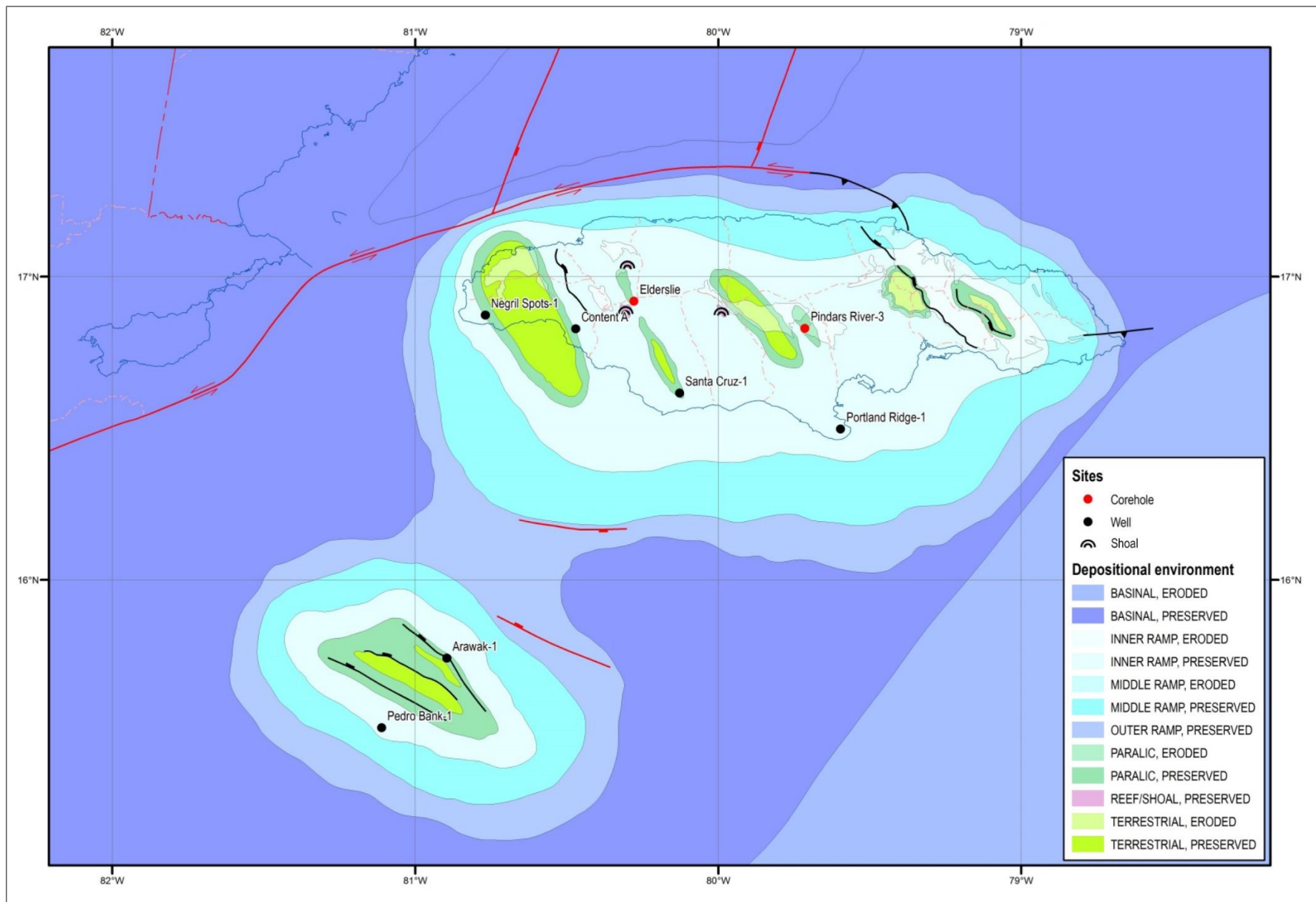
Figure 4. Palaeogeographic reconstruction and gross depositional setting of Jamaica during the YTR2 depositional sequence, approximately 43 Ma.