Arc-Continent Collision: A Comparison of the SE Caribbean and Taiwan-Ryukyu Margins*

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Abstract

Subduction of the combined west-moving North and South American oceanic plates beneath the east-moving Caribbean Plate with consequent development of the Lesser Antilles Arc has long been accepted as a model for collision between two oceanic plates (Figure 1), after Cox and Hart (1986). Earthquake evidence (presented in the form of seismic tomography) supports this model but, additionally, supports subduction of the Caribbean Plate beneath the continental part of the South American Plate (Figure 2), after Pindell and Kennan (2007).

Since the South American Plate is comprised of both continental and oceanic crust which joins at a stable continent-ocean boundary (Guyana COB), it is difficult to reconcile how the Caribbean Plate can both override and be subducted beneath what appears to be the same plate margin. Comparison with the better understood and documented Taiwan-Ryukyu margin provides a model for this arc-continent collision which has been the underlying driver for a world-class petroleum system: *Oil and Gas Journal* reports 79.7 billion barrels of proven conventional oil reserves in Venezuela alone (includes Maracaibo Basin) with as much as 270 billion extra-heavy oil and bitumen in the Orinoco Tar Belt. Crustal loading in advance of the collision creates major accommodation space for sedimentation (reservoir and seal development); it pushes former passive margin source rocks down into the generating window (source maturation below reservoir), and allows space for subsequent tectonic stacking of the recently deposited reservoir and seal sediments (trap development).

While at first the Taiwan-Ryukyu margin may not appear to be a close analogue for the SE Caribbean margin, closer examination reveals a strong similarity. The WNW-moving Philippine Sea Plate can be considered equivalent to the Caribbean Plate while the Eurasian Plate can be considered equivalent to the South American Plate. The Tainan Basin, where loading is currently occurring in

advance of collision, can be considered equivalent to the Columbus Basin. Extensive study of the Taiwan-Ryukyu margin using both surface geology and seismic tomography reveals that the oceanic part of the Eurasian Plate is being subducted beneath the Philippine Sea plate along the Luzon Arc. At the same time, the Philippine Sea Plate is being subducted beneath the continental part of the Eurasian Plate along the Ryukyu Arc (Figure 3).

Suppe (1984) and, more recently Clift et al. (2003) and Sibuet et al. (2004), have developed a workable model for "continuous arc accretion" (Figure 4) where a progressive tear of the crust follows the line of weakness at the continent-ocean boundary (COB) to facilitate the subduction reversal. When viewed from an appropriate geographic perspective, a direct comparison of the two margins can be made (Figure 5). It can be seen that the same abrupt transition between a compressive to tensile regime can be made in both locations. The transition occurs along a zone which Suppe termed the plane of subduction flip.

Comprehension of the Taiwan-Ryukyu arc-continent collision leads to an improved understanding of the SE Caribbean margin (Figure 6). A strong genetic similarity is apparent between the Columbus and Tainan Basins (crustal loading in front of the advancing tectonic front), between the East Venezuela-Trinidad Thrust Belt and Taiwan's Western Foothills (tectonic stacking of recently deposited foreland sediments), and between the Cariaco Trough and S. Okinawa Basin (back-arc rifting in the lee of the advancing arc-continent collision).

Why then has one arc-continent collision given rise to a world-class petroleum system whereas the other has yet to realize major potential? It is suggested that the rate of convergence between plates controls the rate at which the collision zone is laterally propagated. This in turn controls the depth and extent of crustal loading in advance of collision and hence the volume of accommodation space available for reservoir deposition as well as the rate and depth of burial of former passive margin sediments for source rock maturation. The Taiwan-Ryukyu collision, efficient with a closing plate convergence of 82mm/year and lateral propagation of 95 mm/year, leaves little time or space (150,000 km^2) to develop a major petroleum system. The more laborious SE Caribbean collision, with a closing plate convergence of <40 mm/year and similar lateral propagation rate, allows considerably more time for the petroleum system to develop as well as providing a greater area for it to cover (300,000 km^2).

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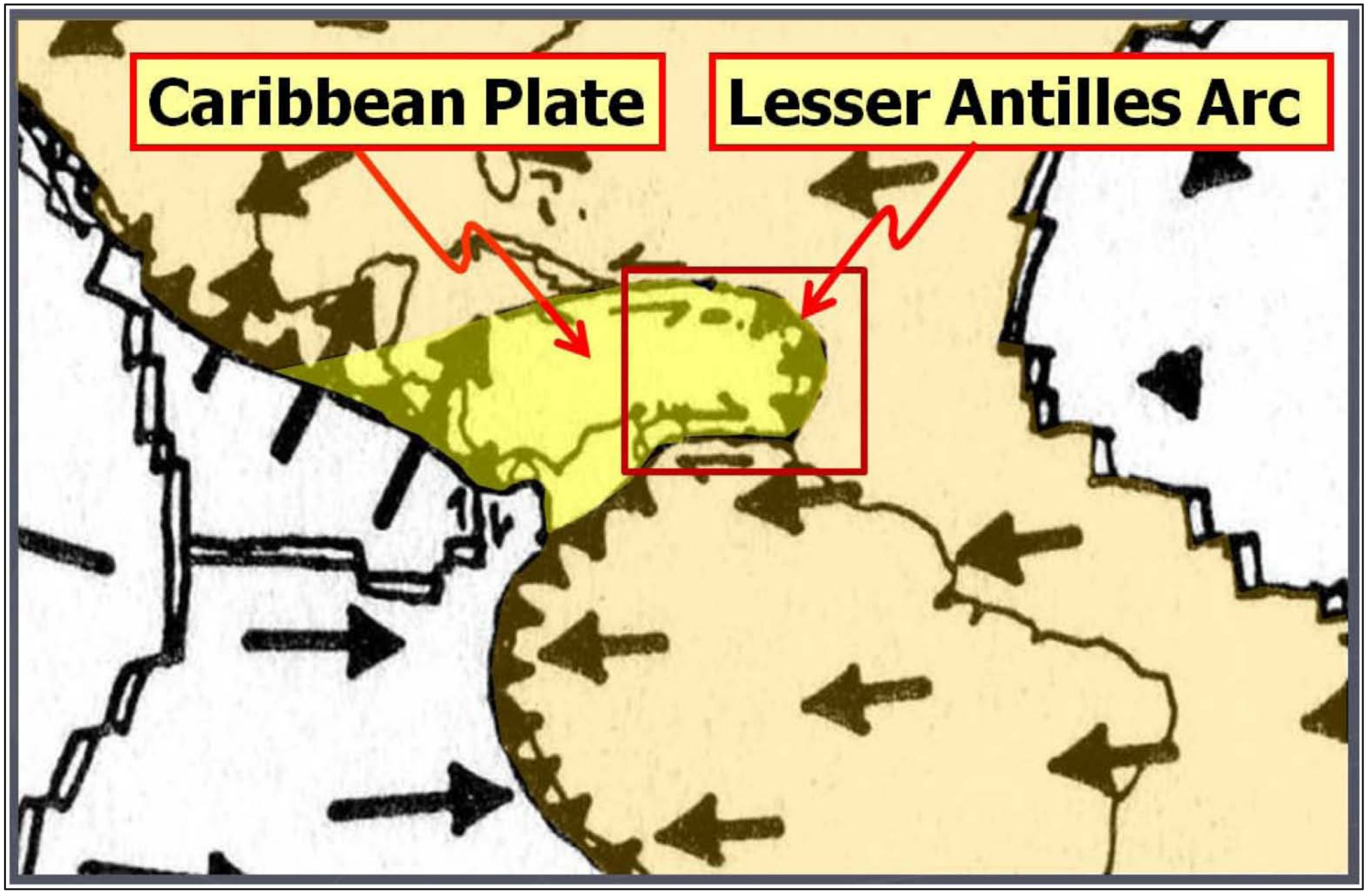

Figure 1. Relative Motion of Caribbean and combined American Plates (after Cox and Hart, 1986).

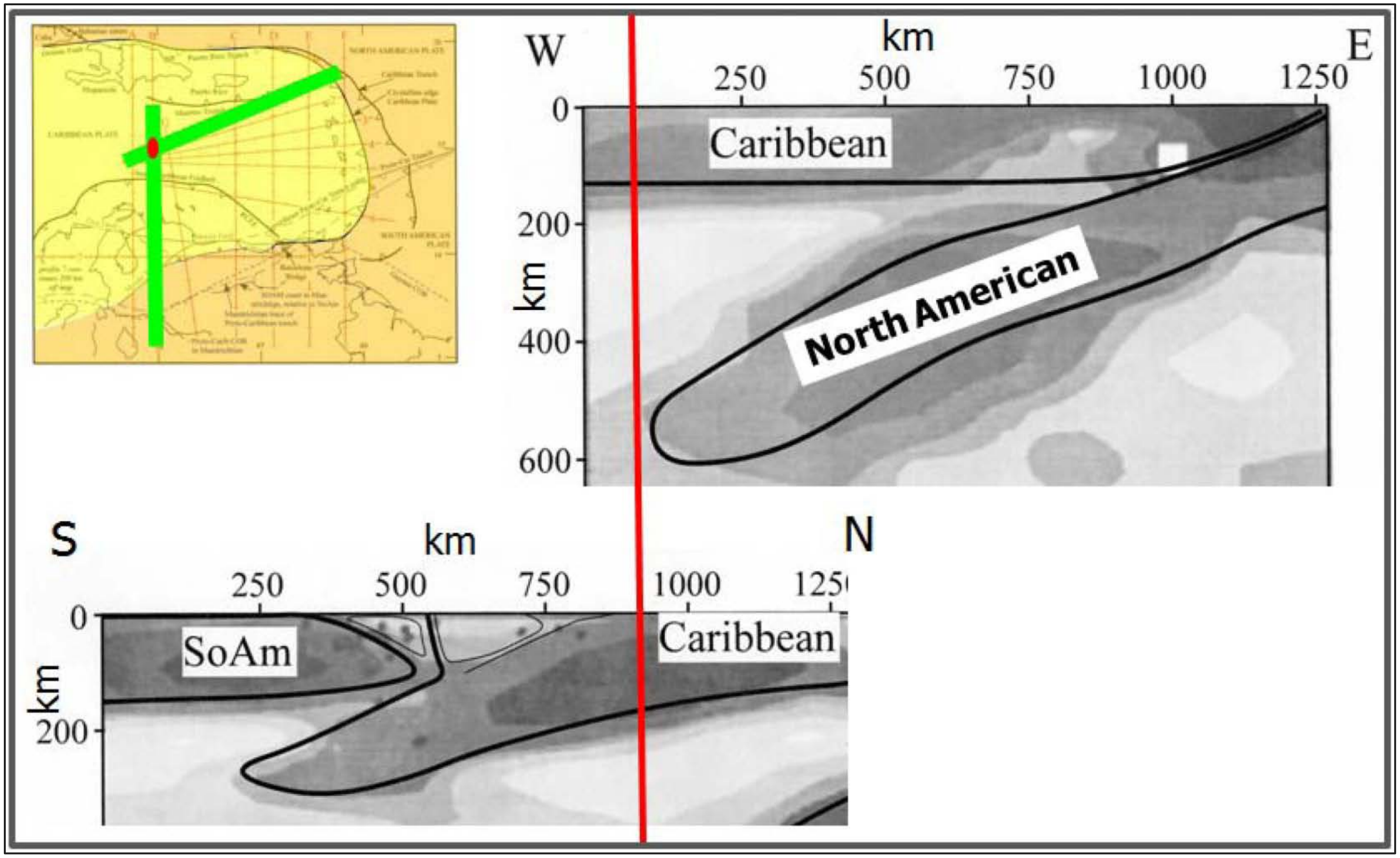

Figure 2. Profiles of Caribbean Plate Margin from seismic tomography, red line indicates point of intersection (after Pindell and Kennan, 2007).

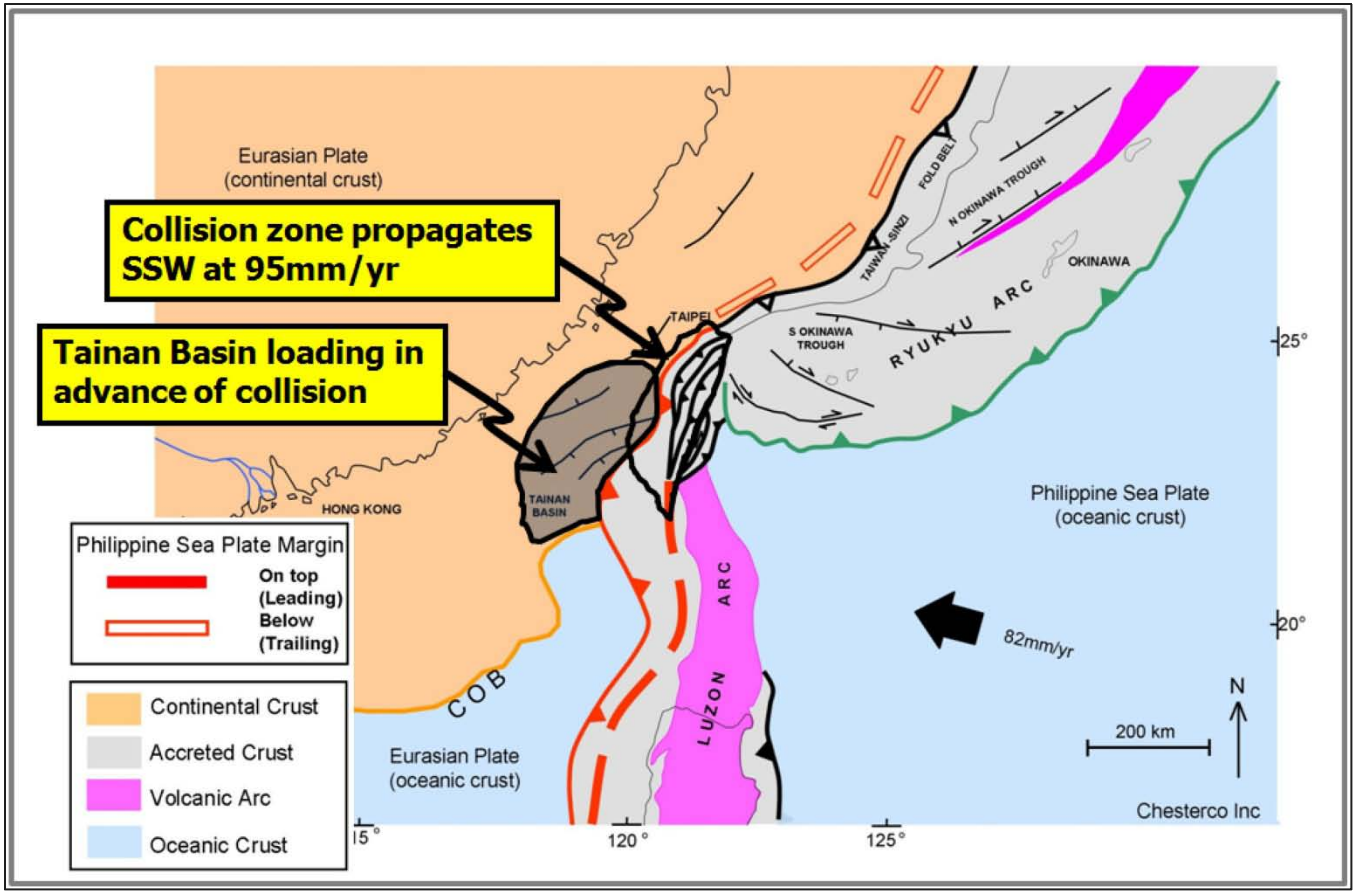

Figure 3. Present-day plate configuration of the Taiwan-Ryukyu Margin.

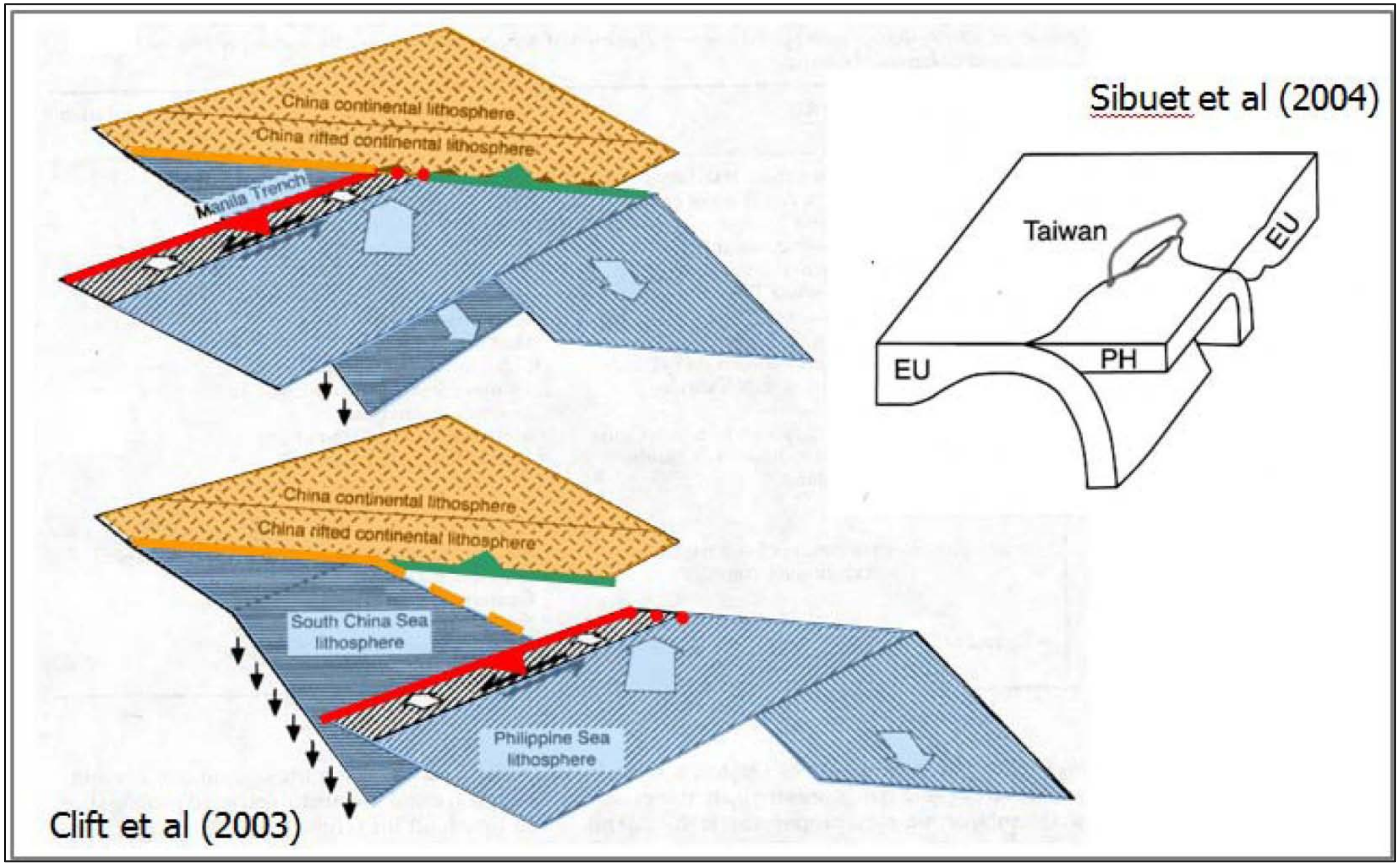

Figure 4. Models of Continuous Arc Accretion (after Clift et al., 2003, and Sibuet et al., 2004).

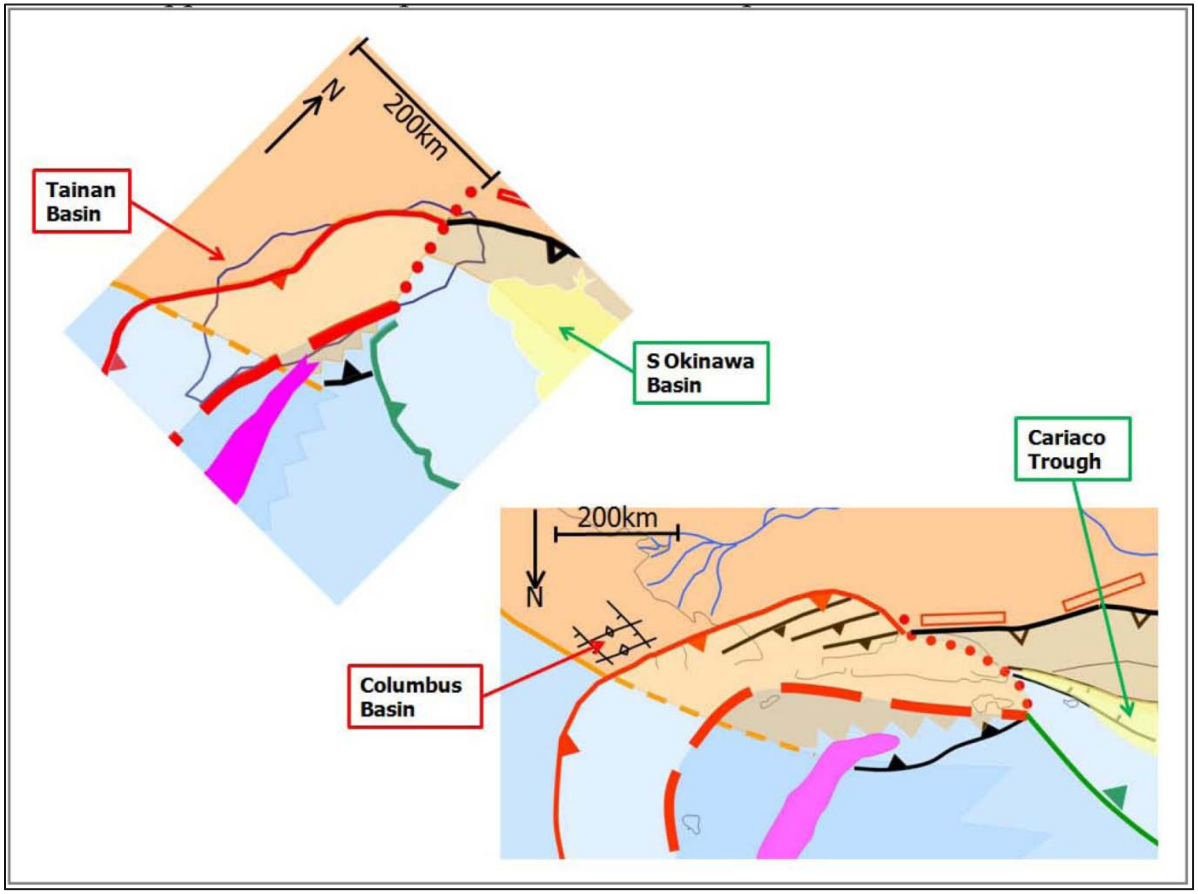

Figure 5. Comparison of the Taiwan-Ryukyu and SE Caribbean Margins; Suppe's Plane of Subduction Flip is indicated by red dots.

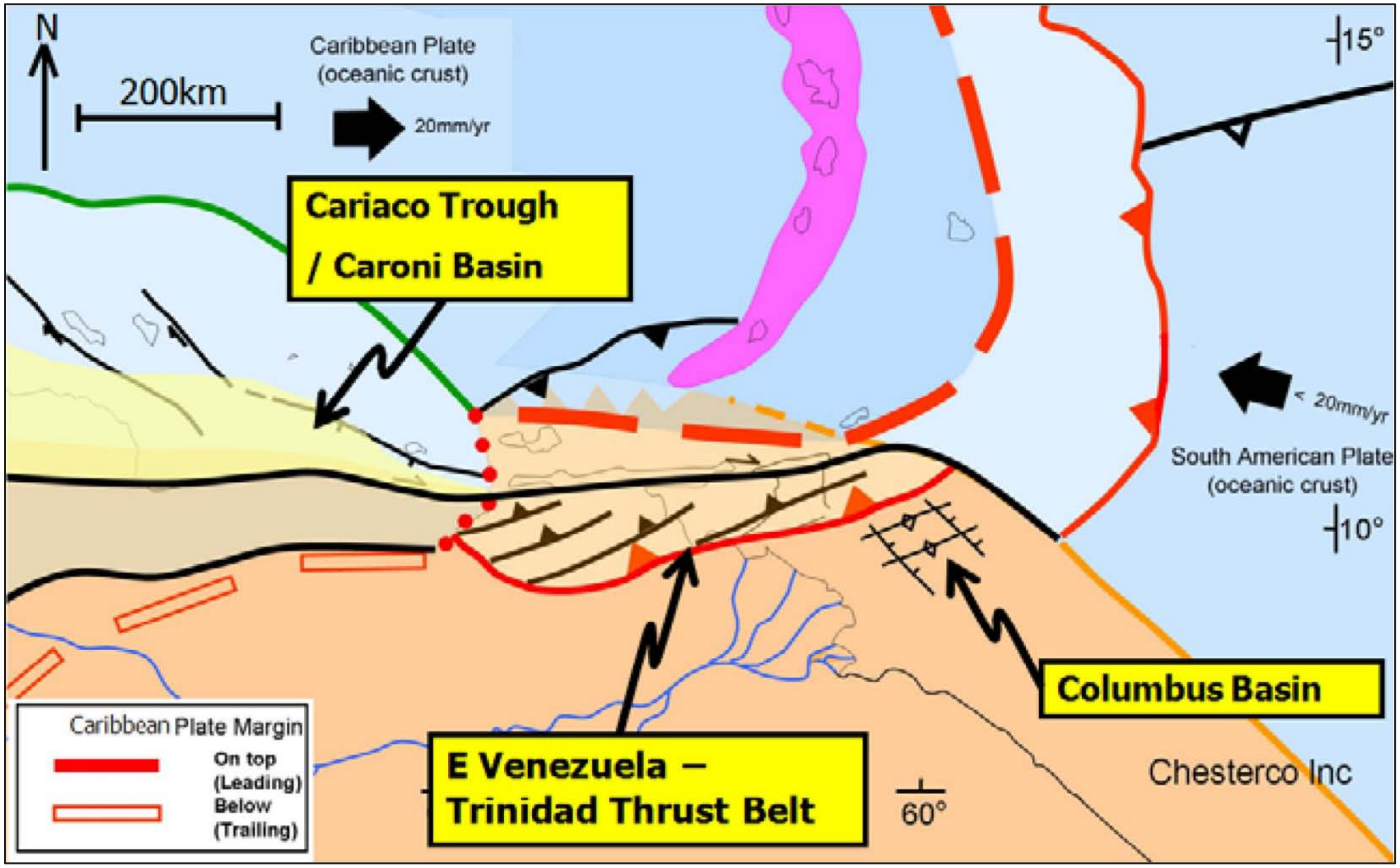

Figure 6. SE Caribbean – Present-day plate configuration using Taiwan model.