WHENCE THE CARIBBEAN?

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(***Editor's note***: This paper was largely modified from the author's original paper which was published in *AAPG Explorer*, August, p. 24 & 26, 2012. Recapture was permitted by AAPG)

The Caribbean has long puzzled geologists. In the first half of the 20th century opinion on its crustal origin was divided between ocean becoming continent and continent becoming ocean – but continent was involved.

In 1966, Tuzo Wilson proposed that the Lesser Antilles volcanic arc was the leading edge of a lithospheric raft moving eastwards relative to North and South America, giving rise to the Pacific – and thus, oceanic – origin of the Caribbean. At the same time the "Plate tectonic revolution" was taking shape.
Since then, the most quoted model for the origin of the Caribbean has been that it formed as Jurassic oceanic crust in the Pacific, where it thickened to a 20-kilometer pile of basalt in the Cretaceous. This collided with an intra-oceanic volcanic arc, driving it east to form the Greater and Lesser Antilles.
The least quoted model, held by a (Galilean) minority that includes me, is that the area evolved in place between diverging North and South America.

While Wilson advanced his ideas, Russian oceanographers (e.g. Beloussov, 1970) urged caution until further data were obtained. Today, they, among others, continue to note abundant samples of continental rocks retrieved from deep oceans and highlight Deep Sea Drilling Project (DSDP) samples of mid-Jurassic to Miocene shallow-water deposits and sub-aerially weathered rocks now at depths of one to seven kilometers in the Atlantic, Indian and Pacific (e.g. Ruditch, 1990; Vasiliev and Yano, 2007; Yano et al., 2009 and 2011).

In the West, Mid-Atlantic Ridge beach sands and continental rocks that puzzled Woods Hole scientist Maurice Ewing (1948, 1949) are generally overshadowed (ignored inconveniences) by the plate tectonic paradigm.

Depending on data
Earlier, Alfred Wegener (1912, 1929) had proposed that continents drifted apart. Original continuity suggested by sedimentology, palaeontology and geometrical fit of shorelines in the south Atlantic was reinforced by the famous Bullard (1965) computer fit of continents along their 2,000-meter deep margins. This, however, had problems of overlap in Central America and the Blake-Bahamas-Florida platform – and ignored data for the Caribbean. British geologist Anthony Hallam (1971) wrote, "Of the alternative initial fits of the continents, that along the boundaries of the Quiet Magnetic Zones is preferred" (see later).

Post-Bullard models creatively reconstructed Middle America by placing continental blocks Maya (Yucatán) and Chortís (Honduras-Nicaragua-Jamaica) (figure 1) in the Gulf of Mexico and alongside southwest Mexico, whence they enthusiastically rotated 135 degrees and 180 degrees anticlockwise into today's positions.

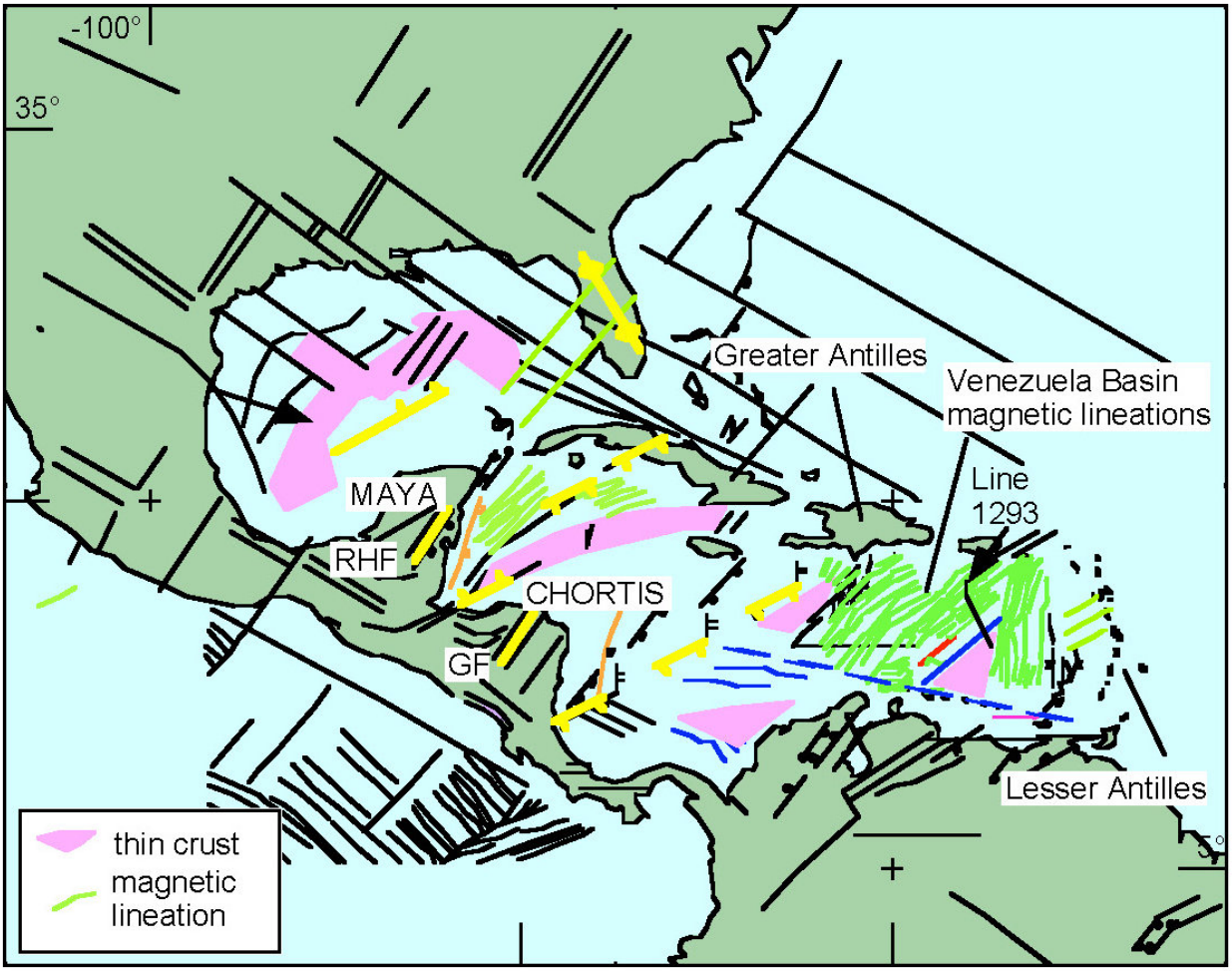

Fig. 1. Tectonic fabric of Middle America. RHF – Rio Hondo Fault, GF – Guayape Fault. James, 2009, Fig. 3.

Or both could have rotated clockwise from the Gulf – there are all sorts of possibilities. Data, however, would have it otherwise.

A northeast trending Jurassic graben (Guayape F.) crosses Chortis, precisely parallel to a similar feature on the Maya (Rio Hondo F., Yucatan). The grabens continue, offset to the east, the trend of Triassic-Jurassic grabens in the Gulf of Mexico, below the Coastal Plain and along eastern North America, where offshore seismic shows seaward-dipping wedges of reflections and drilling has touched salt diapirs. Neither Maya nor Chortis has rotated – Chortis always has been at the western end of the Caribbean and its presence obviates any plate migration from the Pacific.

A few DSDP sites on thick Caribbean crust – the Caribbean "Plateau" – reached upper Cretaceous, shallow marine or sub-aerial basalt. Seismic data show wedges of reflections here as well, below the basalt. "Oceanic" eyes interpret these as volcanic deposits. Peaks, surrounded by moats and rising from the sea floor are seamounts.

These data, however, mimic the north Atlantic Vøring, Møre and Rockall Plateaus, where continental basement lies below sedimentary layers five-10 kilometers thick and basalts. This is the classic signature of submarine extended continent. Thus, in the Caribbean I see continental crust, rifted and extended in the Triassic-Jurassic, Cretaceous carbonates and salt diapirs with rim synclines (figure 2), continuing the geology of offshore eastern North America but including basalt flows.

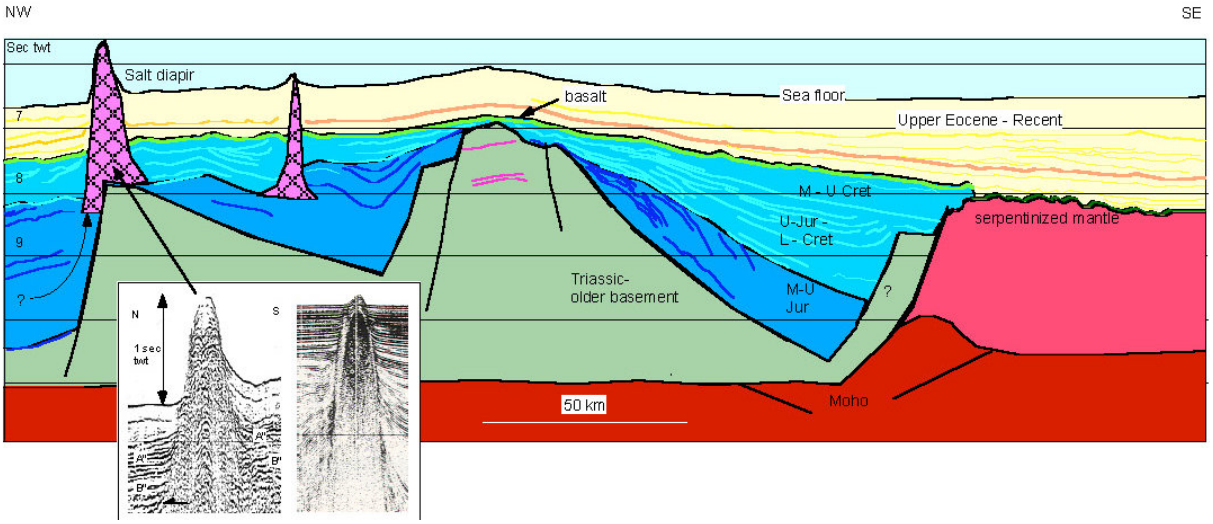

Fig. 2. (Re)Interpretation of seismic line 1293 (location Fig. 1) over the Venezuela Basin. Inset: comparison of "seamount" (left) with drilled, Challenger salt diapir, Gulf of Mexico (right).

Some evidence emerges

Figure 3 shows magnetic data over the south Atlantic. Magnetic stripes attributed to 84 million years of seafloor spreading appear in the center of the ocean. Between these and land the magnetic signatures of South America and Africa show important continuations offshore. Rather than "Cretaceous Quiet Zone" – oceanic crust formed when the Earth forgot to reverse its magnetic field for 40 million years – these areas are subsided, extended continental crust.

Reconstruction of South America-Africa along the margins of these extensions provides the good "Pangaean" fit (figure 3 inset) suggested by Hallam. It shows continental masses significantly larger than currently recognized. Before subsidence, dinosaurs, freshwater fish and snails, mammals and flowering plants migrated merrily along direct, overland routes between Europe, South America, Africa and Madagascar, blissfully unaware of "biodispersal problems."

Drilling in increasingly deep water (current deep rigs rated to four kilometers) is providing evidence of this considerable continental subsidence. Cretaceous shallow marine limestones offshore Brazil now lie at seven kilometers, below thick salt and more than two kilometers of water. The step into deep water and the amazing recent discoveries there (Tupi/Lula) came after new geological concepts and analogs were imported from the North Sea and Gulf of Mexico.

How does this relate to the Caribbean?

If your curiosity is piqued, compare seismic data over the Santos Basin and the Caribbean "plateau" (hints: mobile salt, shelf break carbonate buildups).

Magnetic data over the Caribbean show extended continent signature – classic oceanic magnetic striping is not present. Detailed magnetic data do show lineaments, but these reflect crustal structure. They trend northeast, parallel to the grabens of Maya, Chortís and North America.

What other data support continental origins for the Caribbean? Crustal thicknesses, tectonic fabric, highly silicic volcanic rocks, gravity data, stratigraphy and palaeontology all converge in this direction.

Shallow marine Eocene and Oligocene (on the Bahamas) limestones now kilometers deep show that geologically recent subsidence occurred here also.

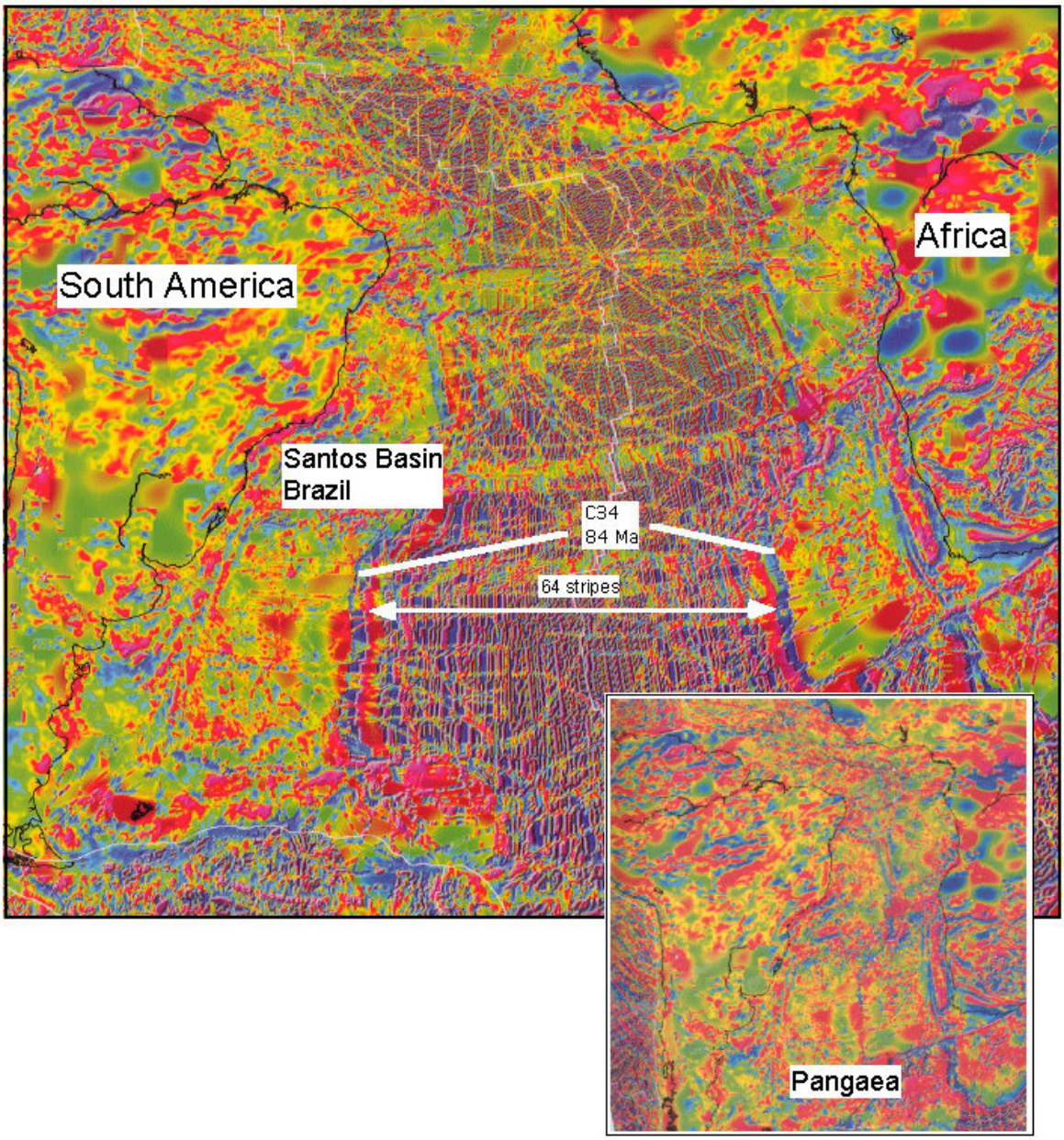

Fig. 3. Magnetic data (from Korhonen et al., 2007, Magnetic Anomaly Map of the World), S Atlantic. Inset: "Pangaean" reconstruction.

The big question
Could hydrocarbons be present in the Caribbean?

The similarity with offshore North America suggests at least a Jurassic system, with associated salt, below the basalts drilled by DSDP.

Basalt is not a problem – Ireland's Corrib Field taps gas from sandstones below basalt and vesicular/fractured basalt hosts oil in Japan's Yurihara Field. Sub-basalt exploration is under way offshore Norway and India.

I'll bet the Caribbean carries significant hydrocarbon resources. I anticipate that changes in vision will lead to these and to paradigm shifts in Caribbean and global plate tectonics.

Whichever model one chooses affects the bottom line for petroleum geology:

- If entirely basaltic and derived from the Pacific, the Caribbean will not carry hydrocarbons.
- If formed in-situ, sharing history with northern South America, the Gulf of Mexico and eastern North America … well, that's another story.

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