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Evolution of the Grenada and Tobago basins and implications for arc migration

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ABSTRACT

The tectonic mechanisms controlling how volcanic arcs migrate through space and geologic time within dynamic subduction environments is a fundamental tectonic process that remains poorly understood. This paper presents an integrated stratigraphic and tectonic evolution of Late Cretaceous to Recent volcanic arcs and associated basins in the southeastern Caribbean Sea using seismic reflection data, wide-angle seismic refraction data, well data, and onland geologic data. We propose a new tectonic model for the opening of the Grenada and Tobago basins and the 50–250-km eastward jump of arc volcanism from the Late Cretaceous Aves Ridge to the Miocene to Recent Lesser Antilles arc in the southeast Caribbean based on the mapping of three seismic megasequences. The striking similarity of the half-graben structure of the Grenada and Tobago basins that flank the Lesser Antilles arc, their similar smooth basement character, their similar deep-marine seismic facies, and their similar Paleogene sediment thickness mapped on a regional grid of seismic data suggest that the two basins formed as a single, saucer-shaped, oceanic crust Paleogene forearc basin adjacent to the now dormant Aves Ridge. This single forearc basin continued to extend and widen through flexural subsidence during the early to middle Eocene probably because of slow rollback of the subducting Atlantic oceanic slab. Rollback may have been accelerated by oblique collision of the southern Aves Ridge and southern Lesser Antilles arc with the South American continent. Uplift and growth of the southern Lesser Antilles arc divided the Grenada and Tobago basins by early to middle Miocene time. Inversion of normal faults and uplift effects along both edges of the Lesser Antilles arc are most pronounced in its southern zone of arc collision with the South American continent. The late Miocene to Recent depositional histories of the Grenada and Tobago basins are distinct because of isolation of the Grenada basin by growth and uplift of the Neogene Lesser Antilles volcanic ridge.

1. Introduction

1.1. Significance

The 11–14-km thick clastic Cenozoic sedimentary rocks filling the Grenada and Tobago basins in the southeastern Caribbean Sea provide a valuable geologic record of the Cenozoic history of the eastwardly migrating Caribbean plate and the evolution of the Early Cretaceous to Recent "Great Arc of the Caribbean" (Burke, 1988; Pindell and Barrett, 1990) (Fig. 1). This study documents the 50–250 km eastward shift of the Caribbean arc system from an older Cretaceous arc along the Aves Ridge to a younger, Miocene to Recent arc along the Lesser Antilles arc system to the east (Fig. 1). Previous studies commonly show both the Late Cretaceous Aves ridge and Cenozoic Lesser Antilles Ridge as adjacent features that coexisted throughout the Cretaceous and Cenozoic rather than explaining how the older, Late Cretaceous arc (Aves Ridge) evolved into the Cenozoic Lesser Antilles arc (Babb and Mann, 1999; Bird et al., 1999; Bouysse, 1988; Burke, 1988; Pindell and Barrett, 1990; Robertson and Burke, 1989; Smith, 1993; Tomblin, 1975).

Debate over the evolution of the Great Arc of the southeastern Caribbean and its related basins has continued for several reasons: 1) previous seismic reflection transects lack sufficient penetration to image the acoustic basement and are not integrated with refraction surveys (cf. reflection and transects shown in atlas compilation by Speed and Westbrook (1984)); 2) previous seismic transects are widely spaced or rely heavily on a single line or derived cross section and therefore may not be representative of the entire arc and basinal structure of the region (Westbrook and McCann, 1986; Westbrook et al., 1988; Ladd et al., 1990); 3) much of

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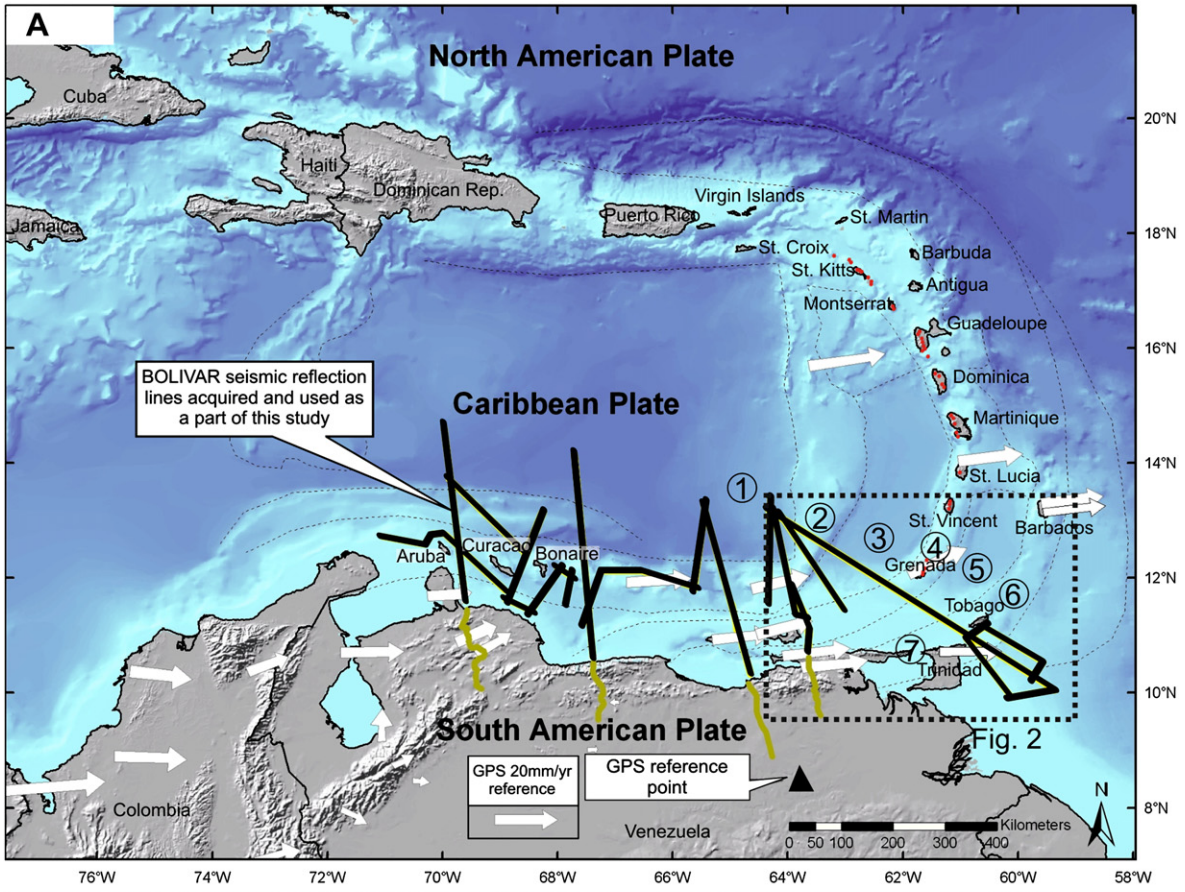
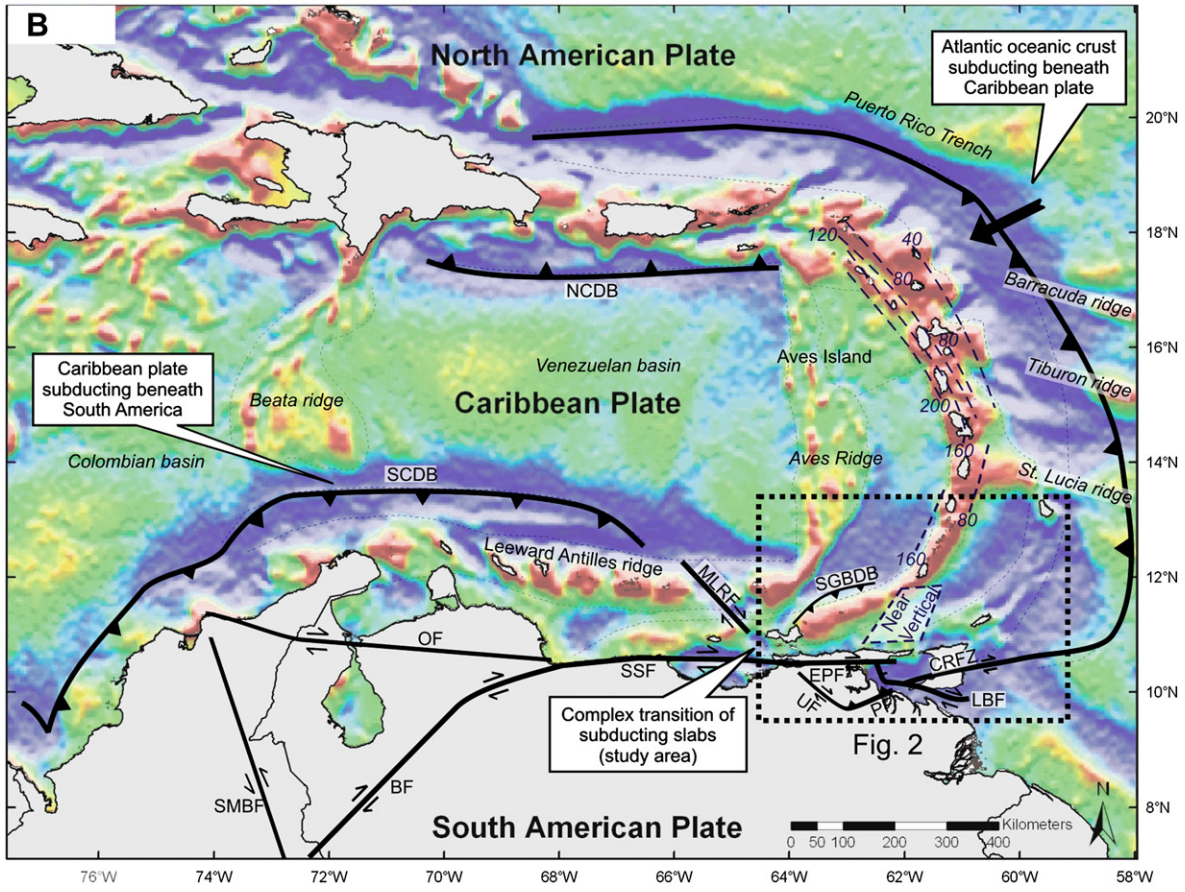

A
North American Plate
Cuba
Haiti
Dominican Rep.
Jamaica
Puerto Rico
Virgin Islands
St. Martin
St. Croix
St. Kitts
Barbuda
Antigua
Montserrat
Guadeloupe
Dominica
Martinique
St. Lucia
St. Vincent
Barbados
Grenada
Tobago
Trinidad
BOLIVAR seismic reflection lines acquired and used as a part of this study
Caribbean Plate
Aruba
Curacao
Bonaire
South American Plate
Fig. 2
GPS 20mm/yr reference
GPS reference point
Colombia
Venezuela
Kilometers
0 50 100 200 300 400
N
20°N
18°N
16°N
14°N
12°N
10°N
8°N
76°W
74°W
72°W
70°W
68°W
66°W
64°W
62°W
60°W
58°W


B
North American Plate
Atlantic oceanic crust subducting beneath Caribbean plate
Puerto Rico Trench
NCDB
Barracuda ridge
Tiburon ridge
St. Lucia ridge
Caribbean plate subducting beneath South America
Venezuelan basin
Caribbean Plate
Aves Island
Aves Ridge
Beata ridge
Colombian basin
SCDB
Leeward Antilles ridge
MLRF
SGBDB
Near Vertical
CRFZ
EPF
LBF
OF
SSF
BF
SMBF
Complex transition of subducting slabs (study area)
Fig. 2
South American Plate
Kilometers
0 50 100 200 300 400
N
120
40
80
80
200
160
80
160
20°N
18°N
16°N
14°N
12°N
10°N
8°N
76°W
74°W
72°W
70°W
68°W
66°W
64°W
62°W
60°W
58°W