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Fast Track Article

Geodynamic model of the northwestern Caribbean: scaled reconstruction of Late Cretaceous to Late Eocene plate boundary relocation in Cuba

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With 3 figures

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Abstract: Reviewing the local geological data of Cuba, its structural relations to Hispaniola and Jamaica as well as a comparison of prevalent plate tectonic models, allow for a refined Late Cretaceous to Miocene tectonic reconstruction. The Cuban orogenic belt records subduction, volcanic arc formation and accretion along the pre-Eocene northwestern leading edge of the Caribbean plate. Geologic evidence points to a two-stage development with change in subduction polarity from a south- and southwest-dipping Cretaceous to a north-dipping Paleocene to Early Eocene subduction zone. During the Late Campanian, the Cretaceous arc collided with the North American continental margin. Ophiolites and parts of the Cretaceous volcanic arc are thrust onto the North American continental margin until the Late Eocene. After the initial Campanian collision, the Caribbean plate continued its relative northward movement. As a consequence, oceanic lithosphere of the back-arc area was emplaced on the top of the southern extension of the inactive arc. During the Danian, a new north-dipping subduction zone was established that consumed oceanic lithosphere of the Caribbean plate until the Middle Eocene. The arrival of thickened oceanic crust of the Caribbean Large Igneous Province stopped the subduction and the relative northward movement of the Caribbean plate. Subsequently, in the Middle Eocene the east-west striking Oriente transform fault system was formed which since then represents the northern boundary of the Caribbean plate.

Key words: Caribbean plate, Cuba, plate tectonics, strike-slip fault, Atlantic, Cuban orogenic belt

Introduction

The left-lateral transform-fault system along the Cayman trough separates the Yucatan basin and the Cuban orogenic belt from the Caribbean plate (Fig. 1). During pre-Eocene times, however, the northwestern Caribbean including broad segments of Cuba have been part of the Caribbean plate (e.g. PINDELL 1994; ROSS & SCOTESE 1988; MESCHEDE & FRISCH 1998; PINDELL & KENNAN 2001; PINDELL et al. 2006).

Western and central Cuba constitute an orogenic belt resulting from the collision of a mid- to Late Cretaceous volcanic arc (CVA) and its associated subduction-accretion complex with Late Jurassic to Late Cretaceous sedimentary rocks of the North American paleomargin. The collision process apparently started in the Campanian (e.g. STANEK et al. 2006). Major north- to northeast-directed thrusting processes culminated during the Paleocene and Eocene (e.g. ITURRALDE-VINENT 1998; GARCIA-CASCO et al. 2008).

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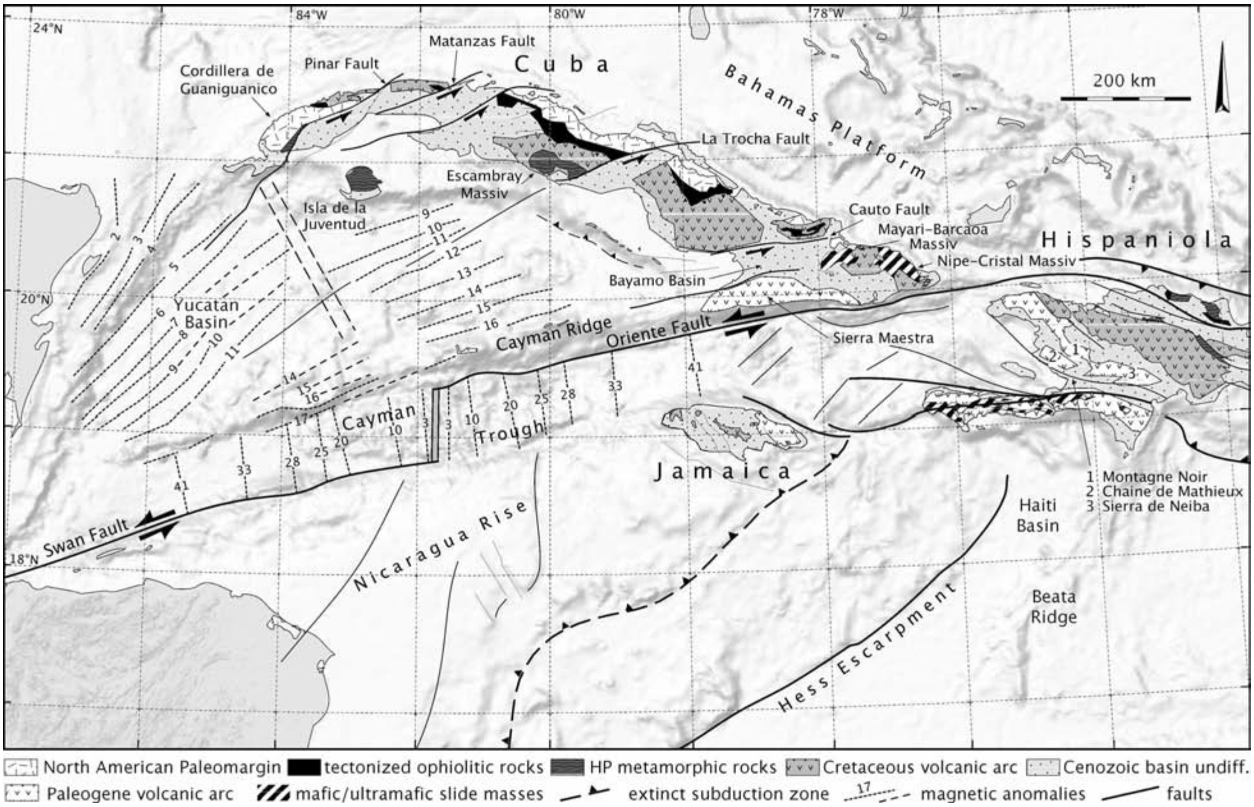

Fig. 1. Structural overview of the northwestern Caribbean and the Mesozoic basement units of Cuba. Bathymetric data: ETOPO2; topographic data: STRM-3; basement faults of the Yucatan basin after ROSENCRANTZ (1996); geology of Cuba generalized from PUSCHROVSKIY et al. (1988), geology of Hispaniola and Jamaica after LEWIS & DRAPER (1990).

The Caribbean is a geologically complex region with several different plate boundary interactions. Up to recent time, some authors are convinced that the paradigm of plate tectonics cannot incorporate the Caribbean region (MORRIS et al. 1990; JAMES 2006). Mobilistic views of the tectonic development of the Caribbean Plate assume significant amounts of eastward migration relative to the Americas, but differ with regard to the total amounts of relative eastward migration and whether to suppose a „Pacific“ or „intra-American“ location of origin (BURKE et al. 1984; DUNCAN & HARGRAVES 1984; DONELLY 1989; GHOSH et al. 1984; PINDELL 1994; BURKE 1988; ROSS & SCOTESE 1988; MESCHEDE & FRISCH 1998; ITURRALDE-VINENT & MACPHEE 1999; KERR et al. 1999; MANN 1999; STANEK 2000; PINDELL & KENNAN 2001; JAMES 2004, 2006; PINDELL et al. 2006). Essential differences are concerning the concepts of active margin developments. Geodynamic reconstructions of the northwestern Caribbean region have been particularly controversial in terms of the number of arcs, subduction polarity, and timing of collision. After all, current models partly contradict or neglect geological facts on the regional and sub-regional scale.

In this paper, we briefly review the Meso- and Cenozoic units of the Cuban orogenic belt and depict results of a Ph D thesis based on interpretation of literature, mid- to high-resolution elevation data, geological maps, and fieldwork results (SOMMER 2009).

Mesozoic units of the Cuban orogenic belt

Four E-W striking units extend parallel to the axis of the Cuban orogenic belt (Fig. 1). From the bottom up (north to south), these units expose (1) mainly Meso-

zoic North American paleomargin, (2) an ophiolite belt, (3) metamorphic complexes within tectonic windows, (4) a Cretaceous volcanic arc suite, and (5) Paleogene foreland and piggyback basins.

North American paleomargin

A fold and thrust belt along the northern edge of the Cuban mainland mainly exposes Mesozoic deposits of the North American paleomargin (e.g. Pardo 1975; Hatten et al. 1988; Pszczółkowski 1999; Cobiella-Reguera 2000; Stanek 2000, Pszczółkowski & Myczynski 2003).

Westernmost Cuba (Cordillera de Guaniguanico) is characterized by thick deltaic sequences of Early and Middle Jurassic age (San Cayetano Formation). Middle Oxfordian to Cenomanian carbonates in the Sierra de los Organos and the Sierra del Rosario trend towards deeper-water deposits. Late Jurassic to Early Cretaceous paleomargin deposits in central Cuba reveal shelf, slope, and continental rise sequences that are characteristic of the Bahamas platform and its southern extension (Pszczółkowski 1999; Cobiella-Reguera 2000; Moretti et al. 2003; Pszczółkowski & Myczynski 2003).

Ophiolite belt

The Northern Ophiolite Belt (NOB) is an ophiolite-bearing mélange-like assemblage. It constitutes an almost continuous body transported from the south over the North American paleomargin (Pardo-Echarte 1996; Cobiella-Reguera 2005). Its outcrops stretch along the northern half of almost the entire island of Cuba.

Tectonized ultramafic rocks and gabbros floating in a serpentinitic matrix are the most common lithologies. Tectonically embedded Mesozoic volcanic and sedimentary rocks are composed of basalts, hyaloclastites, cherts, limestones, shales, eclogites and blueschists (e.g. Kniper & Cabrera 1974; Cobiella-Reguera 1984, 2005; Iturralde-Vinent 1990, 1994, 1996; Millán Trujillo 1996; Kerr et al. 1999).

Sedimentary samples yielded Tithonian, Hauterivian–Barremian and Aptian–Albian fossils (Iturralde-Vinent 1990; Andó et al. 1996; Llanes Castro et al. 1998). A maximum K-Ar age of 160 ± 24 Ma was obtained from anorthosites sampled in Camgüey (Somin & Millán 1981; Iturralde-Vinent et al. 1996).

Geochemically, the basalts of the NOB are grossly characterized as oceanic tholeiites (Iturralde-Vinent 1996a). Some samples have been classified as intraplate lavas, boninites, island arc tholeiites or even back-arc basalts (Fonseca et al. 1990; Iturralde-Vinent 1996a; Kerr et al. 1999).

The southwestern continuation of this ophiolite belt might be traced by the ophiolites of Guatemala and along the northeastern margin of the Guerrero block in central Mexico (e.g. Donnelly 1989; Meschede & Frisch 1998).

Metamorphic complexes

Two tectonic windows within the Cretaceous volcanic arc suite expose high-pressure metamorphic rocks (Escambray Massif, Isla de la Juventud). The dome-shaped metamorphic complexes are tectonically overridden by the CVA units from the south (Millán-Trujillo 1997; Grafe et al. 2001).

The metaclastics, metacarbonates, blueschists and eclogites of the Escambray Complex reveal a north to northwest directed stack of high-pressure nappes (Stanek 2000; Grevel 2000; Stanek et al. 1998). Some of the meta-terrigenous rocks may represent equivalents of the Jurassic paleomargin deposits in the Guaniguanico Mountain Range (Millán & Myczynski 1978; Somin & Millán 1981). Carbonaceous schists and marbles were mainly dated as Late Jurassic to Lower Cretaceous (Millán & Myczynski 1978; Khudoley & Meyerhoff 1971; Somin & Millán 1981).

The tectonically lowermost nappe never exceeded high-grade greenschist-facies conditions. In contrast, the overlying nappes, which represent the subduction-accretion complex associated to the CVA, record evidence of HP/LT metamorphic conditions. According to the age data, subduction began at least as far back as Aptian/Albian. Cooling of the metamorphic units at around 75 Ma correlates to the extinction of the CVA (Schneider et al. 2004; Stanek et al. 2006; Grevel et al. 2006).

The metasedimentary sequences of the Escambray Massif are surrounded and separated by tectonic contacts from the amphibolites, metagabbros and gneisses of the Mabujina Complex (Somin & Millán 1976 in Stanek et al. 2006). The shear zone below the Mabujina unit is the main detachment between the high-pressure metamorphic rocks and the overlying arc complex (Stanek et al. 2006).

Cretaceous volcanic arc

Cretaceous volcanic arc (CVA) units occupy large parts of the Cuban basement below the Cenozoic deposits. Often referred to as “Zaza zone” or “volcanic arc terrane”, these units have an allochthonous structural position, as they are thrust from the south upon the Northern Ophiolite Belt and the North American continental paleomargin (e.g. PARDO 1975).

The earliest metamorphosed products of the initial stage of the CVA may be represented by the Mabujina amphibolites exposed along the northern edge of the Escambray Massif (BOYANOV et al. 1975; SOMIN & MILLÁN 1977; MILLÁN & SOMIN 1985; MILLÁN TRUJILLO 1996; STANEK 2000; STANEK et al. 2006). The age of the protolith of the Mabujina Formation has been estimated paleobotanically as Late Jurassic to Early Cretaceous (DUBLAN et al. 1988). Pb-Pb zircon ages from gneisses gave 90-130 Ma (BIBIKOVA et al. 1988 in STANEK et al. 2006), and SHRIMP zircon dating has yielded 132 Ma (ROJAS-AGRAMONTE et al. 2005a). Geochemically and isotopically, the igneous protoliths of the Mabujina unit are interpreted as island-arc rocks derived from a depleted mantle source with sedimentary contamination (BLEIN et al. 2003).

The Cretaceous arc suite broadly consists of a two stage volcanic development: A primitive pre-Aptian stage is followed by a mainly calc-alkaline Aptian to Campanian phase (ITURRALDE-VINENT 1996b, 1998; DÍAZ DE VILLALVILLA 1997; KERR et al. 1999; STANEK 2000). This development is also reflected by the grouping of granitoid intrusives, which crop out over large areas in the Camagüey area. A presumably Early Cretaceous suite of low K_2O granitoids is succeeded by K_2O-rich granitoids until the early Late Cretaceous (STANEK 2000).

A distinct stratigraphic level in the lower part of the calc-alkaline section of the volcanic arc consists of Albian to early Cenomanian limestone horizons. In some places, the Albian to early Cenomanian limestones occur unconformably with a basal conglomerate. Similar horizons are found throughout the entire Greater Antilles (BOURDON 1985 in DRAPER et al. 1994; KERDRAON 1985 in STANEK 2000) and they approximately correlate with the change in the geochemical signature of the arc. This is consulted by some authors to support the scenario of an Aptian to Albian flip in subduction polarity (e.g. DRAPER et al. 1994; PINDELL 1994; LEBRÓN & PERFIT 1994; DRAPER et al. 1996; COBIELLA-REGUERA 2000; PINDELL & KENNAN 2001; PINDELL et al. 2006).

Rapid uplift and erosion of the arc during the Campanian is indicated by Ar-Ar cooling ages from volcanic and intrusive rocks of the Camagüey area (HALL et al. 2004) and by Campanian-Maastrichtian terrigenous cover beds (COBIELLA-REGUERA 2000). Further indications for a Campanian termination of the arc come from structural and metamorphic data from the Escambray metamorphic complex (STANEK et al. 2006). In western Cuba, post-volcanic cover beds of the arc consist of Campanian to Maastrichtian limestones and conglomerates (Vía Blanca and San Juan y Martínez formations, PIOTROWSKI 1987; PUSCHAROVSKIY et al. 1988).

Cenozoic units of the Cuban orogenic belt

The Cenozoic units of the Cuban orogenic belt comprise: (1) Paleogene basin deposits related to the development of the Cuban fold and thrust belt, (2) a Paleocene to Middle Eocene volcanic arc suite (Paleogene volcanic arc, PVA) with associated marginal basin deposits in south-eastern Cuba (Fig. 1).

Paleogene piggyback and foreland basins

Paleogene foreland basins of the Cuban orogenic belt developed on the Mesozoic paleomargin deposits in the front of the extinct CVA, whereas contemporaneous piggyback basins evolved above the allochthonous thrust units of the arc. Parts of the foreland basins were eventually overthrust by the advancing tectonic prism of the orogenic belt (ITURRALDE-VINENT 1998; SAURA et al. 2008).

From about the Early Eocene onward, northeast-striking transform faults (e.g. Pinar-, Matanzas-, La Trocha-, Cauto faults; Fig. 1) started to dissect the previously compressive structure. Normal offsets of up to several thousand meters induced the development of transtensional basins to the south of the major faults. Simultaneously, deformed basement rocks exhumed on the northwestern shoulders of the transform faults (PUSCHAROVSKIY et al. 1989; GORDON et al. 1997; ITURRALDE-VINENT 1995, 1998; SAURA et al. 2008;).

Syntectonic foreland basin deposits of western Cuba constrain the final collision between the CVA and the North American paleomargin to a latest Paleocene to Early Eocene interval (PSZCZÓŁKOWSKI 1978; BRALOWER & ITURRALDE-VINENT 1997).

The cessation of syn-tectonic deposition apparently becomes younger towards the east. Its end is constrained to the Middle Eocene in the region between La Habana and Ciego de Avila (Kantchev et al. 1976), and to the Late Eocene in the region between Camagüey and Holguín (Nagy et al. 1983; Iturralde-Vinent et al. 1981, 1986). This apparent trisection resembles the Eocene establishment of the left-lateral strike-slip faults, of which the Pinar and the La Trocha faults seem to represent major limitations of individual tectonic blocks.

Overall, latest Eocene deposits discordantly cover the deformed foreland basin deposits, marking the orogen-wide termination of folding and thrusting (Iturralde-Vinent 1978, 1995).

Paleogene volcanic arc and related marginal basin

In southeastern Cuba, the Sierra Maestra (Fig. 1) exposes up to 6000 m of Paleocene to Middle Eocene tholeiitic and calc-alkaline volcanic rocks (Lewis & Straczek 1955; Furrazola-Bermudez et al. 1964; Khudoley & Meyerhoff 1971; Cobiella-Reguera 1988; Iturralde-Vinent 1996c; Méndez Calderón 1997; Rojas-Agramonte et al. 2004). Minor outcrops of the unconformably underlying CVA occur along the southern coastline of the Sierra Maestra (Puscharovskiy et al. 1988)

The sequences of the El Cobre Group are intruded by a large number of bodies and plutons of gabbro, diorite, tonalite, granodiorite and granite composition. Broadly consistent with previous age dating (Iturralde-Vinent 1996c; Rodriguez Crombet et al. 1997; Kysar et al. 1998; Mattietti-Kysar 1999), the granitoid massifs yielded intrusion ages between 60 Ma and 48 Ma based on $^{207}Pb/^{206}Pb$ SHRIMP analyses of single zircons (Rojas-Agramonte et al. 2004).

The rocks of the Sierra Maestra are folded with increasing intensity from south to north, apparently deformed by a collision from the south postdating the Paleogene volcanic arc activity (Rojas-Agramonte et al. 2005b, 2006).

The oldest marginal basin sequences include Maastrichtian olistostromes and large slide masses of mafic and ultramafic rock. The allochthonous massifs (Mayarí-Baracoa and Nipe-Cristall massifs; Fig. 1) either rest on a Maastrichtian olistostrome (La Picota Formation) or directly on the extinct CVA (Fig. 3; Kniper & Cabrera 1974; Cobiella 1978; Draper & Barros 1994; Iturralde-Vinent 1996b; Iturralde-Vinent et al. 2006). In contrast to the intensely sheared ophiolites of central and western Cuba, which have been overridden by the Cretaceous volcanic arc, the mafic and ultramafic massifs of eastern Cuba are only locally deformed.

Tuffs and pyroclastic rocks make up large proportions of the Paleocene basin deposits that accumulated to the north of the PVA (Bayamo – San Luis Basin, Cobiella-Reguera 1988; Iturralde-Vinent 1998).

Similar Paleocene to Middle Eocene rocks have been drilled in the Cayman ridge (Sigurdsson et al. 1997), and the volcano-sedimentary sequences of the Montagne Noir, Chaine de Matheux, Sierra de Neiba on Hispaniola (Fig. 1) are apparently closely related to those of the Bayamo – San Luis Basin and the Sierra Maestra in eastern Cuba (e.g. Butterlin 1960; Lewis & Draper 1990).

The PVA is overlain by Middle Eocene shallow-water limestones. Granitoid clasts in conglomerates of the Camarones Formation indicate that the PVA was already uplifted and eroded to the upper level of its intrusive bodies by the Late Eocene (Puscharovskiy 1988; Rojas-Agramonte et al. 2004).

Mesozoic tectonic history

During the Middle Jurassic, North America rifted away from Africa and South America, opening the Central Atlantic (Klitgord & Schouten 1986). Faunal exchange between the Proto-Caribbean and the Tethys oceans occurred from the Oxfordian onward (Marton & Buffler 1999; Pszczółkowski & Myczynski 2003; Iturralde-Vinent 2003).

The San Cayetano Formation (Cordillera de Guaniguanico, western Cuba; Fig. 1) comprises Early and Middle Jurassic deltaic rift-basin deposits and bimodal volcanic rocks, contemporaneous to those in the Gulf of Mexico (Buffler et al. 1980; Burke et al. 1984; Ross & Scotese 1988; Salvador 1987; Hutson et al. 1998; Kerr et al. 1999; Pszczółkowski 1999; Stanek 2000).

A maximum K-Ar age of was obtained from anorthosites sampled in the NOB. The tectonic position of the NOB and its age data (160 ± 24 Ma; Somin & Millán 1981; Iturralde-Vinent et al. 1996) suggest an origin from Jurassic to Early Cretaceous ocean floor which occupied an oceanic realm south of the Bahamas rift/passive continental margin (Fig. 2a).

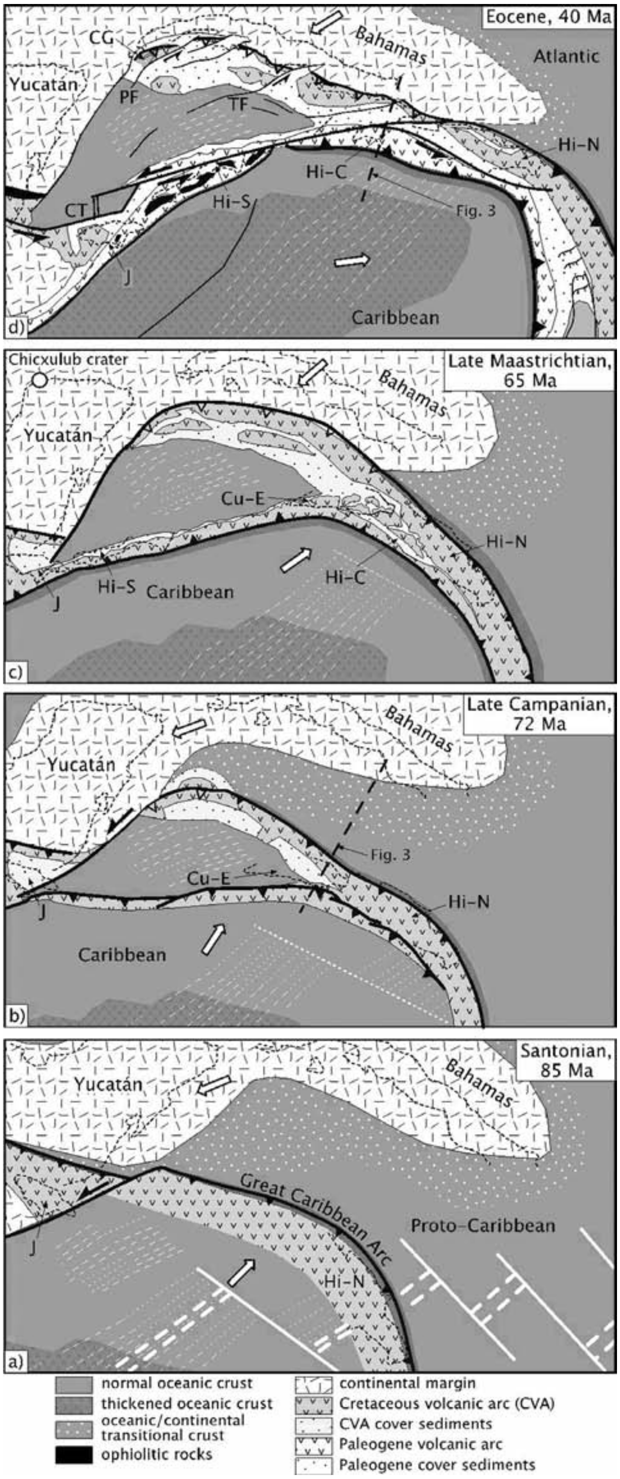

Fig. 2. Plate tectonic reconstructions showing the evolution of the northwestern Caribbean region and the Cuban orogenic belt from Late Cretaceous to Eocene. **CG =** Cordillera de Guaniguanico, **CT =** Cayman Trough, **Cu-E =** eastern Cuba; **Hi-C =** central Hispaniola; **Hi-N =** northern Hispaniola; **Hi-S =** southern Hispaniola; **J =** Jamaica; **PF =** Pinar Fault; **TF =** La Trocha Fault.

An early indication for the beginning of subduction along the northeastern Caribbean realm is represented by the Mabujina amphibolites on Cuba. The protoliths of the Mabujina unit are interpreted as primitive volcanic arc rocks and may be as old as 130 Ma (Millán & Somin 1985; Stanek 2000; Blein et al. 2003; Bibikova et al. 1988 in Stanek et al. 2006; Rojas-Agramonte et al. 2005a). As indicated by the magmatic development in central Cuba (Iturralde-Vinent 1996b, 1998; Díaz de Villalvilla 1997; Kerr et al. 1999; Stanek 2000) and structural/metamorphic data from the Escambray Massif (Stanek et al. 2006), subduction was active at least as far back as Aptian.

On Jamaica, the oldest primitive arc volcanics are of Barrêmian age (~ 115 Ma; Mitchell 2003, 2006), and on Hispaniola, primitive island arc volcanics are of Aptian-Albian age (El Seibo unit, Los Ranchos Formation; Donnelly et al. 1990; Kesler et al. 1991, 2005). The metamorphosed mafic rocks of the Duarte Complex may represent even earlier products of volcanic arc activity on Hispaniola (Draper et al. 1994).

In summary, the magmatic histories of Jamaica, Cuba and Hispaniola point to a beginning of subduction and the formation of a common antecessor of the Greater Antilles Arc (GCA) at some time during the Early Cretaceous (Fig. 2a).

Continuous southwest-dipping polarity of the GCA, at least from the Aptian-Albian until the onset of collision with the Bahamas margin in the Late Campanian (Fig. 2b), can be inferred from (1) its Late Cretaceous approach towards the North American margin, (2) the magnitude of top-to-north directed tectonic transport in the Cuban orogenic belt after the Late Campanian onset of collision, and (3) the internal structures of the metamorphic fore-arc assemblages and their evolution on the north side of the arc.

Due to the latest Paleocene to Eocene age of synorogenic foreland deposits, many workers assumed that the collision process between the arc and the Bahamas Platform did not start before the Paleocene (e.g. Bralower & Iturralde-Vinent 1997; Kerr et al. 1999). However, recent data point to the fact, that the GCA was actually approaching the southernmost extension of thinned continental crust of the Bahamas Platform by the Late Campanian (Fig. 2b, 3a):

(1) As indicated by Ar-Ar cooling ages, magmatism in the Cuban portion of the GCA ended during

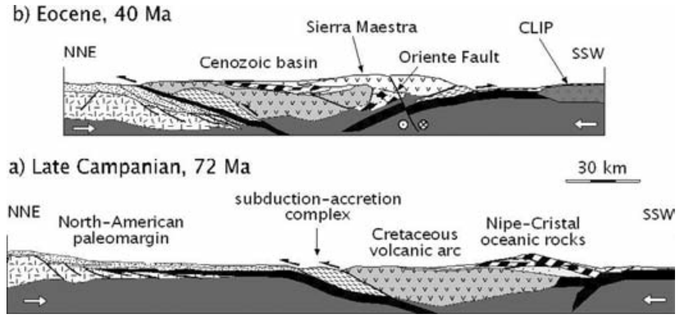

Fig. 3. Cross sections of the Cuban orogenic belt in the Late Campanian and Eocene (locations as indicated in Fig. 2). **CLIP =** Caribbean Large Igneous Province.
See Fig. 1 for further explanation.

the Campanian (Hall et al. 2004). Uplift and erosion of the arc is approved by pressure-temperature-time paths from the Escambray Massif (Stanek et al. 2006) and by Campanian-Maastrichtian terrigenous cover beds which locally crosscut granitoid massifs (Cobiella-Reguera 2000).

(2) Stanek et al. (2006) attribute the late Campanian cessation of magmatism, simultaneous onset of uplift, cooling and erosion to underthrusting of sediments of the Bahamas margin, thickening of the accretionary wedge and shallowing of the subduction angle.

According to the P-T history of the Escambray Massif, actual thrusting of the metamorphic subduction-accretion complex and the extinct arc onto the southern margin of the Bahamas Platform began at about 65 Ma (Fig. 2c) when further cooling of the Escambray and Isla de la Juventud metamorphic units was assisted by extensional tectonic unroofing (Pindell et al. 2005; Stanek et al. 2006).

The Maastrichtian sheets of mafic and ultramafic rocks on top of the GCA units in eastern Cuba (Mayarí-Baracoa and Nipe – Cristall massifs) play a key role to the understanding of the latest Cretaceous and Paleogene tectonic development of the northwestern Caribbean:

Gravitational sliding from a southern location has been proposed as the most probable mode of emplacement of the eastern Cuban ophiolites (Cobiella 1974, 1978; Iturralde-Vinent et al. 2006). The mafic volcanics on the southern peninsula of Hispaniola (Maurrasse et al. 1979; Sayeed et al. 1978; Bellon et al. 1985; Calmus & Vila 1988; Draper et al. 1994) and of the Bath-Dunrobin Complex in Jamaica (Krijnen & Lee Chin 1978; Montgomery & Pessagno 1999) are apparently related to the Mayarí-Baracoa and Nipe-Cristall massifs.

The Northland Allochthon of the Northland peninsula of New Zealand (e.g. Ballance & Spörli 1979; Bradshaw 2004), may represent an analogue to the eastern Cuban ophiolites. A recent model for the origin of the Northland Allochthon is based on the concept of "flake" emplacement at the commencement of subduction (Bradshaw 2004; Gretener 1981).

Regarding the positions of ophiolitic rocks in the Blue Mountains of Jamaica, eastern Cuba, the southern peninsula of Hispaniola and their association with Late Maastrichtian to Early Danian olistostromes, a similar process probably affected the northwestern Caribbean realm before the commencement of the Paleogene volcanic arc. Progression of the collision process between the GCA and the Bahamas margin hampered the Caribbean Plate in its northward relative motion with respect to North America. Continued northward push triggered initial compressive stress and "flake" emplacement which finally resulted in the commencement of north-dipping subduction and the emergence of the PVA.

Cenozoic tectonic history

After the impediment of northward relative motion of the Caribbean Plate and the resulting "flake" emplacements had affected the entire northwestern Caribbean, the PVA spanned the region from the southern margin of the Chortís Block, along the southern boundary of the Yucatán Basin to the southeastern tip of Cuba and the southern half of Hispaniola. Cenozoic sinistral strike-slip along the northern Caribbean Plate boundary and the relative eastward migration of the Nicaragua Rise and the Chortís Block later dismembered the original extend of the PVA (Fig. 2d).

The Paleogene development of the Cuban foreland basins is an expression of the final collision in the Cuban orogenic belt and does not mark the onset of collision. The late tectonic implementation of the Cuban orogenic belt is characterized by

(1) final thrusting episodes in the nappe piles of the Guaniguanico Mountain Range and central Cuba;

(2) obduction of the NOB. The NOB originates from the lower plate oceanic realm south of the Bahamas Platform which was subducted beneath GCA from the north. It may also encompass some primitive arc components from the basement of the GCA, but a Pacific origin as considered by Kerr et al. (1999) can be ruled out from the general tectonic frameset;

(3) exhumation of the metamorphic subduction-accretion complex on the Isla de la Juventud and in the Escambray Massif. Flanking sedimentary basins of the Isla de la Juventud dome and the Escambray Massif record the first pebbles of HP-metamorphic rocks at about 45 Ma (Kantshev et al. 1976, Stanek 2000).

At least from Early Eocene time a significant change started to affect the entire northern Caribbean region. Relative motion of the Caribbean shifted to a more eastward direction with respect to North America. As a result, major northeast trending sinistral strike-slip faults started to crosscut the compressive structures in the Cuban orogenic belt (Pinar, Matanzas, La Trocha, Cauto faults, Fig. 2c, 2d).

From Early Eocene time, transtensional basins (Cuenca Los Palacios, Cuenca Las Vegas, Cuenca de la Broa, Cuenca Central, Cuenca Cauto; Fig. 9) started to accumulate several thousand meters of sedimentary infill (Puscharovskiy et al. 1989; Saura et al. 2008).

North America – Caribbean relative motion began to be increasingly taken up at the site of the sinistral Oriente Fault and the Cayman Trough. Regarding the probable Early Eocene opening of the Cayman Trough (Rosencrantz et al. 1988; Leroy et al. 2000), the initiation of the major strike slip faults in the Cuban belt may even predate the Early Eocene.

As outlined above, relative northward motion of the Caribbean Plate was impeded from the late Campanian – Maastrichtian onward which resulted in the commencement of north-dipping subduction and the emergence of the PVA. Due to a continuous clockwise rotation of the North America – Caribbean relative motion, the PVA probably faced increasingly oblique subduction in its northwestern portion during Paleocene to Middle Eocene.

Simultaneous Middle Eocene cessation of PVA activity was probably caused by the arrival of the Caribbean Large Igneous Province (CLIP) at the subduction zone (Fig. 2d, 3b). Deformation of the rocks of the Sierra Maestra might be attributed to the collision of the CLIP. This collision stopped any northward component of relative movement of the Caribbean Plate. As a result, North American – Caribbean relative motion began to be taken up mostly at the site of the sinistral Oriente Fault and the Cayman Trough. Spreading at the Mid-Cayman Rise probably began during the late Early Eocene (Rosencrantz et al. 1988; Leroy et al. 2000; Fig. 2d) and linked the Oriente Transform Fault with the Swan Island Transform and the Motagua–Pólochic Fault System. The Caribbean Plate including the Cortís Block and the Nicaragua Rise effectively started relative eastward movement towards the free space in the eastern Atlantic.

As evident on Hispaniola, the present day Oriente Transform Fault splits eastward into a multibranched fault system. Restoring the south-central part of the island including the Presqu' ile du Nord-Ouest, the Montagne Noir, the Chaine de Matheux, and the Sierra de Neiba to a Middle Eocene position off the coast of eastern Cuba accounts for an approximate Cenozoic displacement of 200 to 300 km between the Cordillera Central and south-central Hispaniola. With regard to an estimated amount of 800 to 1000 km of sinistral offset along the Oriente Fault, most of its eastern prolongation must be accommodated between the south-central part and the southern peninsula of Hispaniola. Restoring an approximate amount of 800 to 1000 km of relative eastward movement places the southern peninsula of Hispaniola to a Middle Eocene position south of the Cayman Rise (Fig. 2d).

According to this reconstruction, the Cayman Ridge and the Sierra Maestra only preserve the northernmost fringes of the PVA which was almost completely dismembered by Cenozoic strike-slip since the Middle Eocene reconfiguration of the northern Caribbean Plate boundary.

Conclusions

Various plate tectonic models of the Caribbean have been proposed over the last decades. With regard to the northwestern Caribbean, geodynamic reconstruc-

tions are particularly controversial in terms of the number of involved arcs, subduction polarity, and timing of collision.

A careful review of the local geological data of Cuba, its relations to Hispaniola and Jamaica as well as a comparison of prevalent plate tectonic models, allow for the proposal of refined Late Cretaceous to Miocene tectonic reconstructions (Sommer 2009).

Inferences from the published data and tectonic reconstructions comprise some essential elements for any evolutionary synthesis of the Caribbean region:

1) The Mabujina amphibolites on Cuba and the Duarte Complex on Hispaniola point to a primitive initial GCA-activity as early as 130 Ma. During the Aptian – Albian, the GCA was fully developed in its juvenile stage.

2) Continuous southwest-dipping polarity of the GCA, at least from the Aptian – Albian until the Late Campanian onset of collision with the Bahamas margin, can be inferred from (a) its Late Cretaceous approach towards the North American margin, (b) the magnitude of top- to north-directed tectonic transport in the Cuban orogenic belt after the Late Campanian onset of collision, and (c) the internal structures of the metamorphic fore-arc assemblages and their evolution on the north side of the arc.

3) The collision of the GCA with the Bahamas margin hampered relative northward motion of the Caribbean Plate from the late Campanian onward. Continued northward push finally resulted in north-dipping subduction and the emergence of a Paleocene to Middle Eocene volcanic arc (PVA) which spanned the northwestern Caribbean along the southern margin of the Yucatán Basin while the Chortís Block and the Nicaragua Rise were still in a paleoposition to the south of the Maya Block.

4) The Maastrichtian commencement of north-dipping subduction was accompanied by superposition of oceanic crust and large-scale north-directed gravity sliding on the upper plate, as documented by ophiolitic slide-masses and Maastrichtian olistostromes in Jamaica, eastern Cuba, and the southern peninsula of Hispaniola.

5) Sinistral strike-slip and associated basin formation in the Cuban orogenic belt point to continuous clockwise rotation of North America – Caribbean relative motion during the Paleocene. Relative northward motion of the Caribbean stopped after the Eocene arrival of thickened oceanic crust at the north-dipping subduction zone of the PVA.

6) After the late Early Eocene commencement of spreading at the Mid-Cayman Rise, North America – Caribbean relative motion was taken up along the sinistral Oriente Fault and its eastern and western prolongations. This transform margin dissected and dismembered the former extend of the PVA with estimated amounts of 800 to 1000 km offset along the Oriente Fault since the Middle Eocene. If south-central Hispaniola is restored to a Middle Eocene position to the south of eastern Cuba, most of the total Oriente offset must be accommodated at the northern bounding-faults of the southern peninsula of Hispaniola.

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