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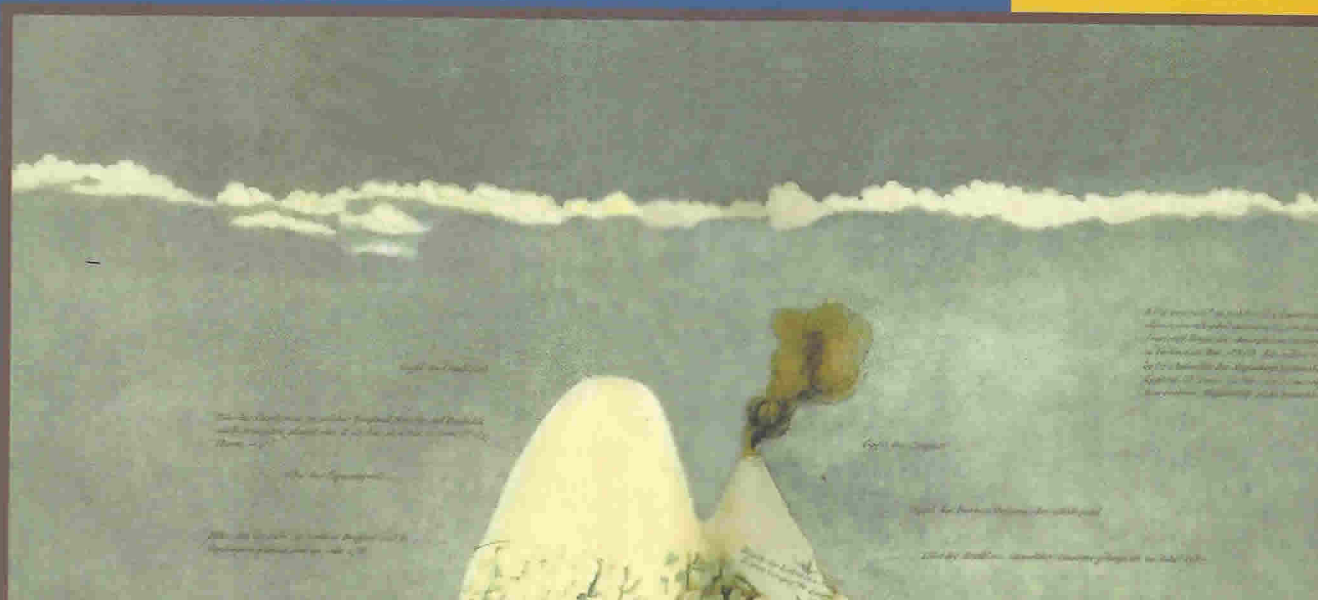

Geoscientific Cooperation with Latin America

Tectonics around the Caribbean Plate

Geological Development of Cuba

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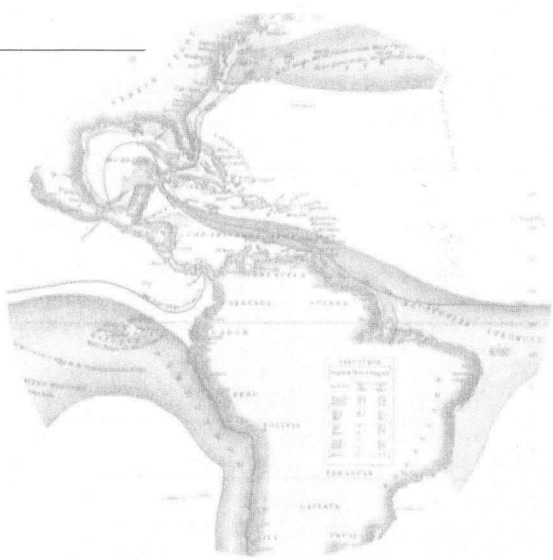
ABSTRACT

The geology of Cuba is a record of the Late Cretaceous to Paleogene collision between a northeastward-moving Cretaceous island arc and the heterogeneous, serrated continental margin of North America. A stack of nappes composed of typical passive margin sediments from the Yucatan Peninsula is exposed in Western Cuba. Central Cuba contains the suture zone between the island arc and associated ophiolites to the south with the carbonate-dominated margin of the Bahamas platform to the north. Isolated metamorphic complexes with high-pressure rocks are exposed south of the suture in tectonic windows, in which ages of 140 Ma have been obtained for high-pressure metamorphism in eclogites and blueschists. A younger, Paleogene island arc is exposed in the Sierra Maestra of Eastern Cuba. The collision first involved oblique interaction with the NE-trending Yucatan margin, perhaps as early as the Cenomanian, before direct docking on the NW-trending margin of the Bahamas platform occurred. We suggest that the younger Paleogene arc was initiated by polarity reversal after docking of the north-facing Cretaceous arc. The 140 Ma age from the high-pressure rocks indicates that the Cretaceous island arc may have incorporated rocks originally metamorphosed along the western margin of the Americas.

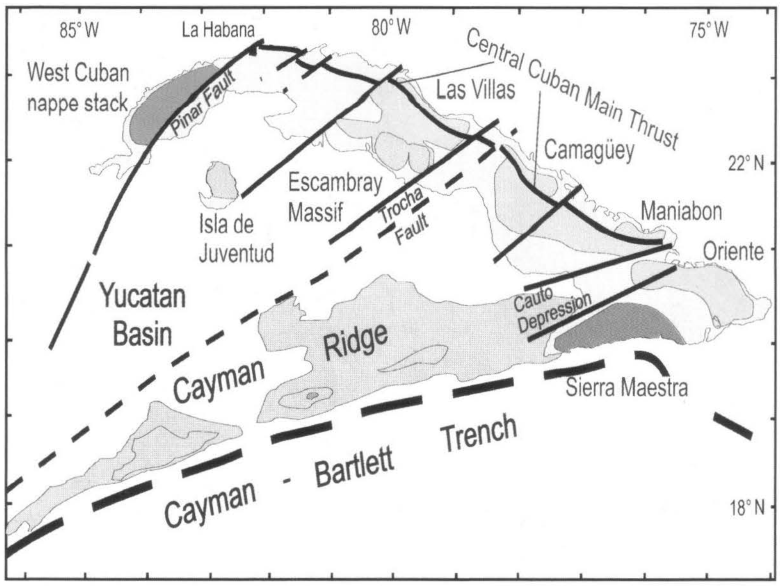
RESUMEN

La geología de Cuba contiene un registro de la colisión entre un arco de islas con desplazamiento hacia el nordeste y el heterogéneo e irregular margen continental norteamericano desde el Cretácico tardío hasta el Paleógeno. En el sector occidental de Cuba los sedimentos del margen pasivo de la península de Yucatán conforman un apilamiento de napas, con sobrecorrimiento hacia el norte. En Cuba central, se encuentra la sutura tectónica entre el arco magmático y las ofiolitas asociadas del Sur, con la plataforma carbonática de las Bahamas en el Norte. Se encuentran complejos metamórficos aislados con rocas de alta presión en ventanas tectónicas al sur de la sutura, con edades de 140 Ma en eclogitas y esquistos azules. Un arco de islas más joven, Paleógeno, está expuesto en la sierra Maestra del oriente de Cuba. La primera colisión involucró una interacción oblicua con la trinchera NE del margen de Yucatán en el Cenomaniano, previo a un "estacionamiento" directo contra la trinchera NW del margen de las Bahamas. Se sugiere que el arco de edad paleógena tuvo en su inicio una polaridad reversa después del choque del flanco norte del arco cretácico. La edad de 140 Ma de las rocas de alta presión indica que el arco de islas cretácico pudo haber incorporado rocas originalmente metamorfizadas a lo largo del margen occidental americano.



Introduction

■ The northwestern Caribbean region is one of the key areas for understanding Mesozoic-Cenozoic plate movements in the intra-American area. This part of the Caribbean (Fig. 1) consists of a triangular, fault-bounded geotectonic element situated between the pre-Mesozoic basement blocks of the Bahamas platform to the north and the Yucatan platform to the west. Cuba, the westernmost island of the Greater Antilles, the oceanic Yucatan Basin and the Cayman Ridge are the major features of the region. Along the southern margin, the Cayman-Bartlett Trench (Fig. 1) is the locus of a major transform fault separating the North American and Caribbean plates. Sinistral movement began in the



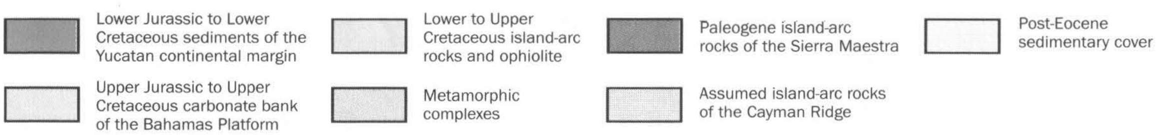


Fig. 1:

Geologic sketch map of Cuba and adjoining areas.

Eocene and separated this part of the Caribbean from the main eastward-moving Caribbean plate to the south. As a result, Cuba was sutured onto the North American plate and has not been affected by the major post-Paleogene shearing that has destroyed much of the direct evidence for Cretaceous tectonic history in the rest of the Greater Antilles to the east.

During the last decades, East German and Cuban geologists have cooperated with other socialist countries in major geological mapping and exploration projects. Beginning in the nineties, the German Research Society funded German geologists and petrologists working jointly with various Cuban institutions on clarifying the evolution and structure of the metamorphic complexes exposed on the island. Due to political circumstances, many important results of mapping and exploration have remained unpublished. In this communication, we offer a brief up-to-date overview of some of the important aspects of Cuban geology that must be considered when developing plate tectonic models of the Caribbean region (cf. the articles of MESCHEDE et al. and MARESCH et al. in this volume). For further details and a compilation of the existing literature reference can be made to STANEK (1999).

Current views on the geology of Cuba

Three main geologic domains can be distinguished on the basis of stratigraphy, type of magmatic activity and tectonic style. These domains are separated (and in part also internally dismembered) by NE-trending, sinistral faults oblique to the axis of Cuba (Fig. 1). The westernmost domain comprises the West Cuban nappe stack. In Central Cuba, between the Pinar fault to the west and the Cauto Depression to the east, the Central Cuban Main Thrust represents the suture between the Cretaceous oceanic island arc and ophiolites of Cuba with the thinned continental crust of the Bahamas platform. In the Oriente Domain of Eastern Cuba, an east-west trending Paleogene island arc is well exposed in the Sierra Maestra (Fig. 1). The Cayman Ridge is presumably the western continuation of the arc, as indicated by ODP drilling which sampled rocks similar to the Sierra Maestra.

Western Cuba

The West Cuban nappe stack (Fig. 1), which originated by northward thrusting in the Paleogene, represents the most complete stratigraphic section available of the passive Protocaribbean margin formed by rifting and separation of North and South America. It comprises several tectonostratigraphic units reflecting distinct tectonic environments. The lowermost units are composed of coeval Early Jurassic to mid-Cretaceous deep-water, slope and platform deposits of a continental passive margin. The transition from continental, rift-type sedimentation to a later marine environment in this section is accompanied by Callovian to Oxfordian basic magmatic activity (Cobiella-Reguera 1996). The stratigraphic record is interrupted in the Cenomanian-Turonian. Karst formation can be observed in Cenomanian carbonate rocks, and in the latest Cretaceous, clastic sediments with volcanic detritus were deposited. Available evidence suggests that this margin was the southeastern margin of the Yucatan Peninsula (Hutson et al. 1998; Stanek 1999, and references therein). At the northernmost and structurally highest position of the nappe pile, a fault-bounded unit with olistoliths of Cretaceous carbonates (Guajaibon unit) has been related to deposits of the Bahamas platform to the northeast (Stanek 1999). The uppermost Bahia Honda unit comprising ultramafic and volcanic rocks of a Cretaceous island arc was thrust from the south.

Central Cuba

Central Cuba consists of two juxtaposed tectonostratigraphic terranes, sutured along the Central Cuban Main Thrust (Fig. 1). A northeast-moving Cretaceous island arc has overridden sediments of the Bahamian continental slope, now exposed as a fold-thrust belt north of the suture line (Fig. 1). These deformed continental slope sediments offer a much more condensed stratigraphic section than the deposits exposed in the West Cuban nappe stack. Sedimentation is dominated by marine carbonates of Late Jurassic to Maastrichtian age, in which the typical environments corresponding to platform, continental slope and pelagic sedimentation environments can be distinguished. Sedimentation in the slope and pelagic environments was interrupted in the mid-Cretaceous, after detritus from metamorphic rocks and serpentinites appeared in the stratigraphic profile.

To the south of the suture, almost complete sections of the oceanic basement underlying the island arc are found in the Camagüey ophiolite (Fig. 1). In the Las Villas and Camagüey regions (Fig. 1), the island arc suites are dissected by NE trending fault zones such as the Trocha Fault. Due to block rotation and differential uplift, various erosional profiles allow a complete section of the Cretaceous volcanic arc and its related plutonic rocks to be reconstructed (e.g. Stanek 1996, 1999).

On the basis of geochemistry and mode of occurrence, the volcanic and plutonic rocks of Las Villas correspond to the primitive island-arc rocks of the eastern Greater Antilles (Stanek 1996). Bimodal igneous suites constitute the roots of the island arc, characterized by a K-poor, oceanic affinity. Preliminary dating of zircons in granitoids yields minimum ages of 110 Ma. During the mid-Cretaceous, arc activity produced a volcanic section several kilometers in thickness, intruded by both calc-alkaline and alkaline granitoids. Two parallel magmatic axes of the Cretaceous arc are preserved in the Camagüey area, indicating space-time variations in the magmatic front. The northern axis consists of bimodal, K-poor igneous rocks of presumably pre-Albian age, whereas the southern axis is represented by a mid-Cretaceous calc-alkaline igneous suite. Granitic stocks, pegmatites and related felsic lavas represent the last magmatic pulse of the Cretaceous arc. Rb–Sr data on magmatic white mica point to 80–90 Ma as the crystallization age for such rocks. They are unconformably overlain by Upper Campanian to Maastrichtian conglomerates and carbonates.

To the SW of the island-arc/Bahamas suture, isolated uplifts of metamorphic rock (Fig. 1) rise above the low-lying volcanic rocks and their post-Eocene sedimentary cover (Isla de Juventud, Escambray Massif, Fig. 1). Late Jurassic to Early Cretaceous fossils are preserved in some marbles, so that the protoliths of the exposed metasediments have been correlated with the passive margin sequences of the West Cuban nappe stack (Millàn & Myczynski 1978).

Detailed study of the eastern part of the Escambray Massif has shown that this massif also represents a pile of at least four nappes. Rock fabrics indicate ductile thrusting to the north.

Carbonate and quartz-mica schists are the dominant lithology, as might be expected from a passive margin sequence (see above). Boudins of eclogite and blueschist-facies rocks occurring in certain tectonostratigraphic horizons indicate high-pressure metamorphism, which can be taken as evidence for a subduction-zone event. Ferruginous quartzites in the enclosing metasediments contain the high-pressure mineral deerite, so that subduction and peak metamorphic conditions of 500–600°C and 20 kbar can be assumed for most of the Escambray Massif. Available geochronological data in the literature (see STANEK 1999) suggests 100 Ma as the age of the high-pressure metamorphism, but there is mounting evidence on the basis of discordant zircons in eclogites and blueschists of our own sample array that a high-pressure event at approximately 140 Ma is recorded.

The tectonically highest nappe of the eastern Escambray Massif is represented by low-pressure /high-temperature, amphibolite- to greenschist-facies rocks comprising the basement of the Cretaceous island arc. Thus, the Escambray Massif actually exposes the tectonic contact zone between a high-pressure, subduction-zone unit and the corresponding island arc. The 90–80 Ma old granitic pegmatites of the island arc (see above) also cut the foot-wall shear zone between island-arc and high-pressure rocks, thus yielding a minimum age for juxtaposition and metamorphism of the two contrasting nappes. Subsequent cooling/uplift of the whole complex through the 280 ± 30°C isotherm can be constrained by fission-track dating on zircon (BRIX, pers. commun. 1999), which yields ages ranging between Latest Cretaceous and Paleocene, depending on tectonic position in the nappe stack. Late overgrowths of lawsonite + pumpellyite in the high-pressure rocks are evidence for a discontinuous, kinked exhumation P-T-path, similar to the one described for high-pressure rocks of the southern margin of the Caribbean region (cf. MARESCH et al., this volume). In the Middle Eocene the metamorphic complex was unconformably covered by chalky sediments. Final neotectonic uplift began in post-Oligocene time.

Eastern Cuba

This easternmost region of Cuba exhibits an extraordinary geotectonic edifice. The tectonically lowest rocks of the Bahamas platform are overthrust by the Cretaceous island arc in the Maniabon area (Fig. 1). To the south and southeast, the Cretaceous island arc is itself overridden by the Oriente ophiolite (the largest ophiolitic mass of the northern Caribbean) which caps the entire nappe stack and constitutes the eastern part of the exposed Oriente block. Below the ophiolite, the Cretaceous island-arc volcanics and carbonates of the Bahamas continental margin locally exhibit a blueschist-facies metamorphic overprint. In contrast to Central Cuba, arc-related magmatism was active from Early Paleocene to Middle Eocene. This Paleogene island arc is well exposed in the Sierra Maestra (Fig. 1), but its relationship with the ophiolites and the Bahamas sediments to the east is masked by clastic sediments of the Guantanamo basin. The first magmatic pulse in the Early Paleocene consisted of bimodal, K-poor volcanics and related granitoids. The distribution of igneous rocks in the Sierra Maestra (and in the southwestern part of the adjoining island of Hispaniola to the south) suggests a south-facing island arc, which ceased activity during the formation of the Cayman-Bartlett transform fault.

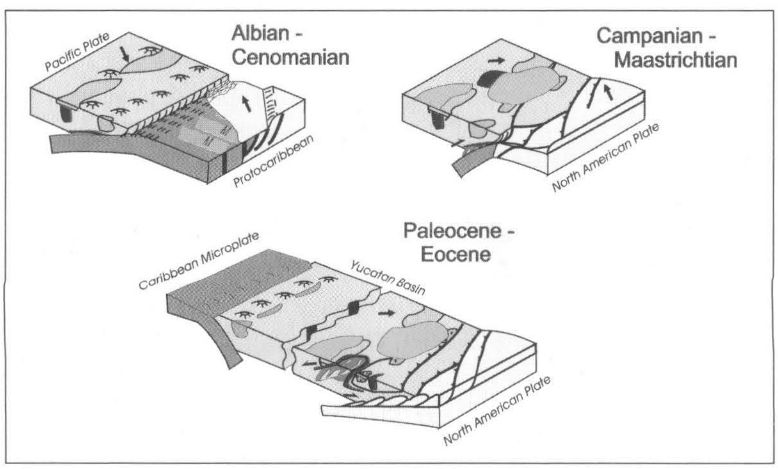
Geodynamic implications

The sedimentary sequences found in the West Cuban nappe stack and north of the Central Cuban Main Thrust yield information on the breakup of Pangea and the nature of the Protocaribbean rifted margins. The western Cuban sequences accumulated along a NE-trending depression at the eastern Yucatan margin (cf. STANEK 1999). Deposition began in the Lower Jurassic with clastics of the San Cayetano Formation (cf. HUTSON 1998). The actual break-up of Pangea and the transition to marine pelagic sediments can be correlated with Callovian to Oxfordian mafic magmatic activity (COBIELLA-REGUERA 1996). Whereas the eastern Yucatan margin was a typical passive continental margin, the southern margin of the Bahamas platform originated as a major NW-trending sinistral fault zone connecting NE-trending rift basins such as the one along the Yucatan margin (e.g. STANEK 1999). Upper

Jurassic sediments unconformably covered Paleozoic or older basement and Upper Jurassic evaporites of the Bahamas platform.

One feature common to current plate tectonic models of the Caribbean area is the concept of a Cretaceous island arc (often termed the "great arc") sweeping east- to northeastward and subducting much or all of the oceanic crust formed during rifting between North and South America. The actual origin of the "great arc" is controversial. One class of models derives the present Caribbean plate from the Pacific. The "great arc" would then have originated as an intra-American extension of subduction zones along the western margin of the Americas (e.g. Pindell & Barrett 1990). This arc then swept eastward through the entire intra-American gap. A polarity reversal of the island arc is postulated by most authors (e.g. Pindell & Barrett 1990), but alternatives have been suggested (Stanek 1999). Another class of models (cf. Meschede et al., this volume) suggests that the Caribbean plate is an intra-American feature. The subduction zones along the western margin of the Americas thus delineate the western rim of the Caribbean plate. In this model, the "great arc" is postulated to have formed as a mid-Cretaceous, intra-oceanic island arc that isolated the Caribbean plate as a piece of intra-American oceanic crust from the Atlantic oceanic crust to the east.

In the northern Caribbean area, the "great arc" collided with the Bahamas platform and was sutured to the North American plate. The geology of Cuba documents this collision well, especially in the Central Cuban Domain. The final stages of the collision appear to have been diachronous, ranging from Late Paleocene to Early Eocene in western Cuba and younging eastward to the Middle Eocene in Central Cuba (Gordon et al. 1997). Current models (e.g. Pindell & Barrett 1990; Meschede et al., this volume) date the initial stages of the collision of the "great arc" with the southern margin of North America as Paleocene. However, there is evidence to suggest that interaction of the island arc with the Yucatan margin and the Bahamas platform may have already begun in the Late Cretaceous. In both areas, the deposition of marine sediments ceased in Cenomanian to Turonian times. Chert, radiolarite, bentonitic clay, sandstone, fragments of ultramafic as well as K-rich volcanic rock, and metamorphic minerals such as glaucophane and staurolite are observed in the stratigraphic record, a fact that can be interpreted as signaling the approach of the island arc.



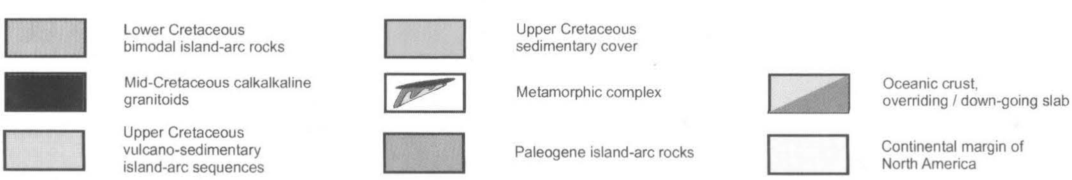


Fig 2:

Schematic development of the northwestern Caribbean area, as derived from the geological history of Cuba. For further explanation see text.

With the observations considered in this paper as a guiding template, we present the scenario indicated in Figure 2 as a working hypothesis. A northeastward sweeping "great arc" begins to interact with the sedimentary apron of the Yucatan margin in the Cenomanian and incorporates a major part of this stratigraphic section as part of the West Cuban nappe stack. The actual beginning of the collision with the Bahamas platform in a strict sense is difficult to pin-point precisely, because flexural bulges in front of the advancing island arc may have affected the depositional environment on the Bahamas well ahead of the arc, and because the island-arc trench may have acted as a channel for rapid eastward movement of continental detritus from the Yucatan margin. Nevertheless, we postulate that collision already commenced in the Late Cretaceous, led to cessation of magmatic activity along the "great arc" in this area, and initiated a new arc via polarity reversal in the Paleocene. This younger arc is now exposed in the Sierra Maestra of eastern Cuba and presumably extends to the west as the Cayman Ridge.

The age of initiation of activity along the "great arc" is of considerable importance for distinguishing between the different classes of Caribbean plate tectonic models. The oldest dated magmatic rocks in the "great arc" on Cuba crystallized at least 110 Ma ago. Although our studies on the metamorphic complex exposed in the Escambray Massif are still in progress, the evidence for a high-pressure event at 140 Ma as a lower intercept in a discordant zircon array from eclogites and blueschists is critical. These data proves that the "great arc" contains subduction-related high-pressure rocks as old as Upper Jurassic to Lower Cretaceous. We conclude that the "great arc" must have originated along the western margin of the Americas and incorporated rocks formed in that realm.

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