

# **THE CARIBBEAN PLATE AND THE QUESTION OF ITS FORMATION**

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review:

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# THE CARIBBEAN PLATE AND THE QUESTION OF ITS FORMATION

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## ABSTRACT

Two different models are presented of how the Caribbean might have formed. The Pacific model assumes the formation of the Caribbean plate at the Galapagos hotspot in the Pacific Ocean during the Middle Cretaceous. Subsequently, the Caribbean plate moved along major strike-slip faults into a pre-existent Jurassic Proto Caribbean basin between North and South America. The Alternative model inferred an intra-plate history of the Caribbean between both Americas as a result of the eastward trending spreading axis of the Jurassic Atlantic Ocean. Both models become similar with the beginning of the Cenozoic. The phenomenon of a 15 to 20 km thick oceanic crust is speculated to be related to the Galapagos hotspot. The Alternative model does not give any explanations or hypothesis for its generation. Data of the Nicoya complex, a complex of ophiolitic rocks occurring in Western Costa Rica and thought to be part of the ancient Caribbean oceanic crust, show ambiguous isotope signature for intra-plate mafic rocks; island-arc signatures are also possible. Palaeomagnetic measurements assumed movements of the Nicoya complex of only 10° latitude. The geochemical investigations as well as palaeomagnetic data are in contradiction to a formation within the Pacific plate. The relatively eastward movement of the Caribbean plate is inferred in both models. At the northern plate boundary the Motagua-Polochic fault, a sinistral strike-slip fault, accommodated most of the displacement. The southern plate boundary is marked by transcurrent motion and thrusting, causing the destruction of useful geological data. It is not possible to give a defined theory about the formation of the Caribbean plate – further studies are necessary.

## 1. GEOGRAPHIC POSITION OF THE CARIBBEAN

The Caribbean consists mainly of the Caribbean Sea and its surrounding landmasses (Figure 1). The Caribbean Sea is the southern part of the Middle American Ocean and thus, a part of the Atlantic Ocean between Central, North and South America, the Lesser Antilles, Haiti and Jamaica. It covers an area of about 2,7 million km<sup>2</sup>, and has an average depth of 2490 m and a maximum depth of 7680 m in the Cayman Trough.

The Caribbean also consists of island arcs, like the Greater Antilles (Cuba to Puerto Rico), the Leeward Antilles, the Lesser Antilles and the Costa Rica-Panama arc in Central America. The Yucatan Basin and the Cayman Trough are two of the famous ocean basins within the Caribbean Region. There are also some important valleys (Ulua Valley in Northern Honduras) and mountain ranges (Central Cordillera of Colombia).

Target areas for further field studies are mostly the following two countries: Guatemala and Honduras. But Nicaragua, Panama, Jamaica and Venezuela are some other countries of geological interest. These regions could have played an important role during the formation of the Caribbean.

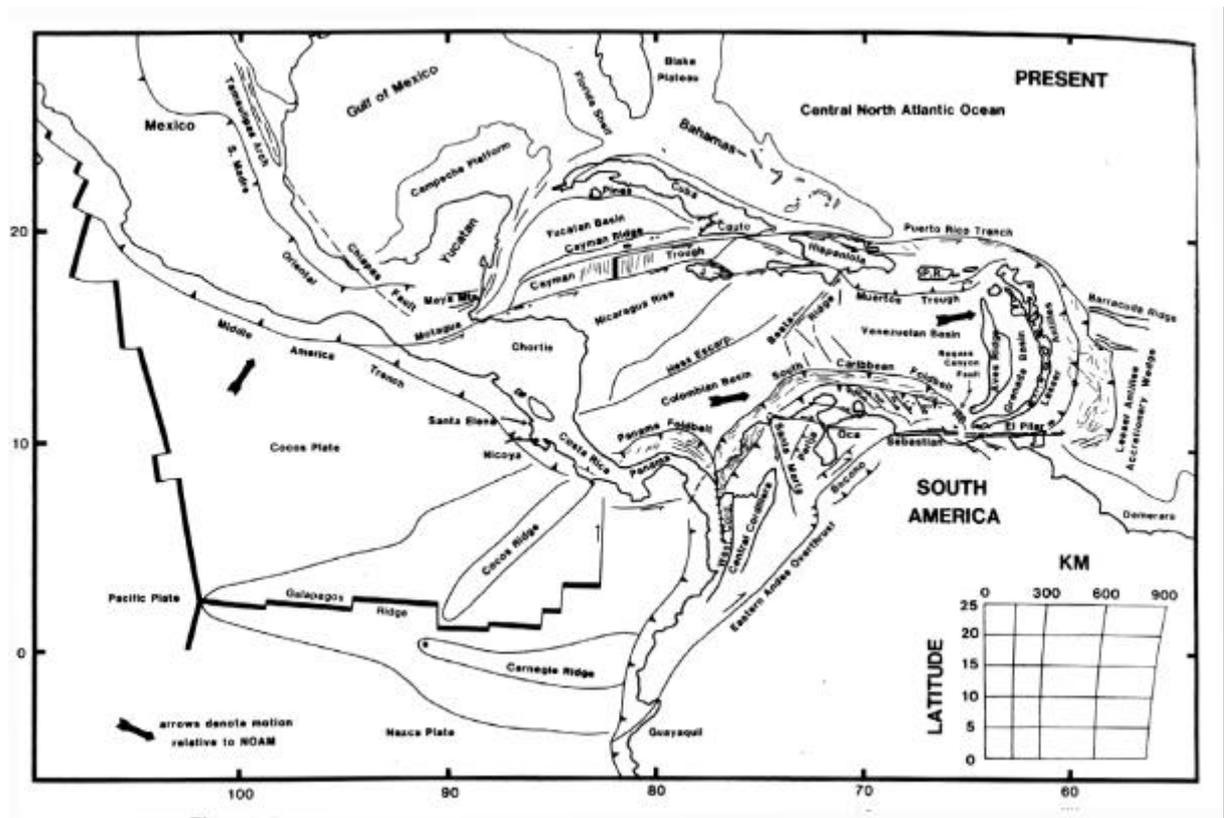


Figure 1. Geography of the Caribbean (Pindell and Barrett, 1990)

## 2. TECTONICAL AND GEOLOGICAL OVERVIEW

### 2.1. PLATE BOUNDARY ZONES

Plate tectonic models of the Caribbean region are based on the relative motions of the North American, South American, African and Farallon plates. This reconstruction shows an overlap between South America and parts of Southern Mexico during the Triassic and the Middle Jurassic (Meschede and Frisch, 1998). To solve this space problem, great sinistral strike-slip shear zones are assumed. Major shear zones are for example the Trans-

Mexican volcanic belt (TMVB, Figure 3) and the Motagua-Polochic fault system (MP, Figure 2).

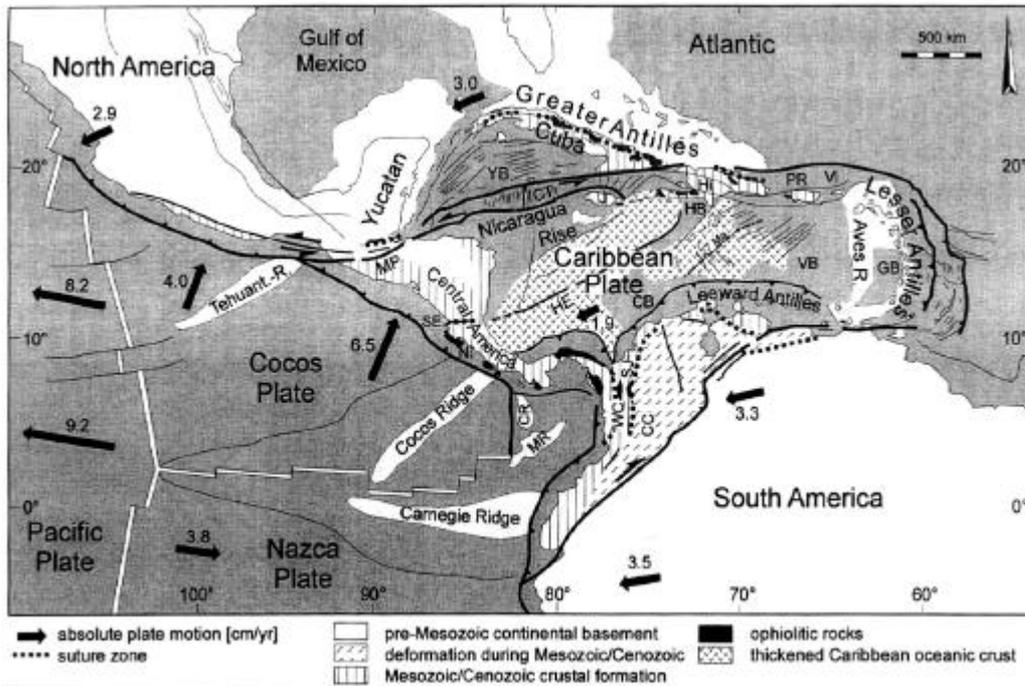


Figure 2. Tectonic overview of the Caribbean plate (Meschede and Frisch, 1998)

the northern plate boundary within the Early Eocene and contemporaneously cease of subduction related volcanism at the southern plate boundary. Later strike-slip occurred in the South with an eastward displacement of about 1000 km relative to South America and more than 100 km thrusting in southeastern direction. The strike-slip displacement has produced very complicated northern and southern plate boundaries.

### 2.1.1. THE NORTHERN CARIBBEAN PLATE BOUNDARY ZONE

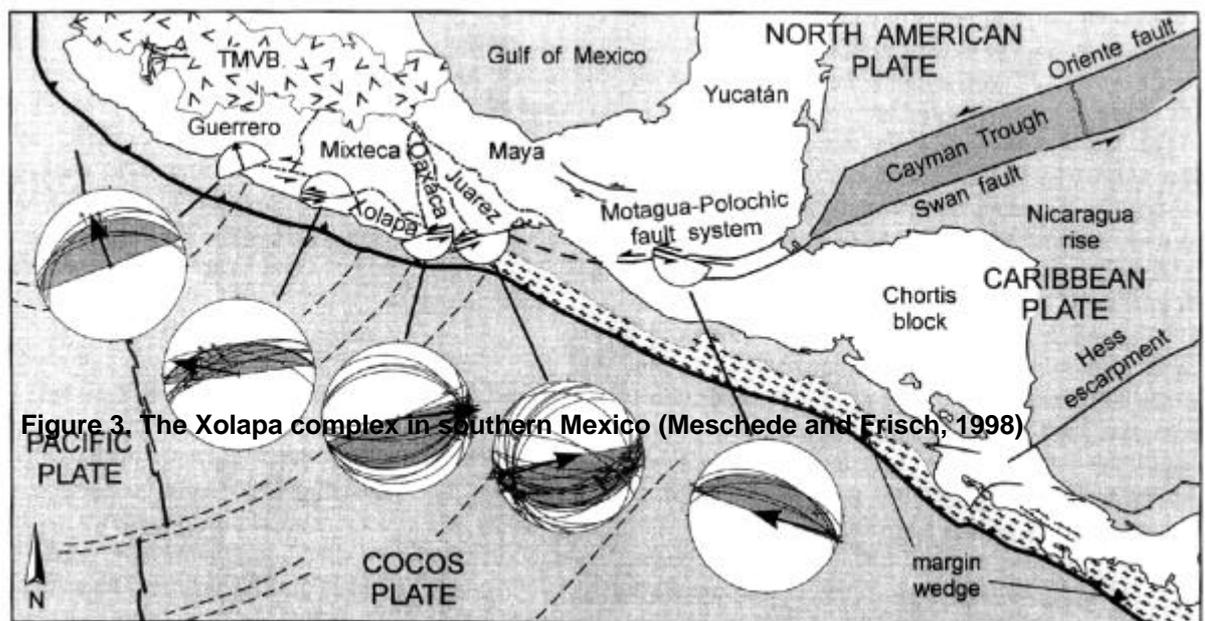
The northern plate boundary is dominated by strike-slip motions along major fault systems, such as the Motagua-Polochic fault zone and the Oriente fault. The boundary extends from Central Guatemala through Jamaica, Hispaniola and Puerto Rico to the Northern Lesser Antilles. It includes the Cayman Trough, a pull-apart basin within the Caribbean Sea. Cuba, as a part of the Greater Antilles and belonging to the Caribbean, does not belong to the Caribbean plate. It forms part of the North American plate since its collision with the Bahamas in the Palaeocene. Today it is separated from Hispaniola, still part of the Caribbean plate, by the Oriente fault, a major strike-slip system in the eastern part of the Cayman Trough. There is mainly north-south compression with southward thrusting in Hispaniola because of its eastward divergence from Cuba and the thereby caused convergence between Hispaniola and the Southeastern Bahamas. The western part of the northern plate boundary is marked by the Motagua-Polochic fault system in Guatemala and Honduras. The valley of the Rio Motagua is the place of this major sinistral strike-slip fault. North of this zone there is the Maya block, a part of the Yucatan peninsula and in the south the region is called the Chortis block. During Mesozoic times the Chortis block moved away from Southwest Mexico to its present position. Therefore the Mesozoic sediments are similar in Southwest Mexico and on the Chortis block, and differ from those of the Maya block, now situated between both areas. The northern

The Caribbean plate is bounded in the West by the Middle American subduction zone and in the East by the Lesser Antilles subduction zone. The northern and southern boundaries are not as well defined. During the Eocene two different developments took place in the Caribbean. There were arc-volcanism and compressional tectonics including arc-continent collision

boundary of the Southern Mexican Xolapa Complex (Figure 3) is marked by mylonitic and cataclastic rocks. These rocks represent a shear zone parallel to the active trench and a branch of the Motagua-Polochic fault zone into Southwest Mexico. The mylonites show N-S extension and sinistral strike-slip deformation. They are the result of the adjustment of the continental margin to changes in plate-tectonic setting during Campanian to Oligocene (Ratschbacher et al., 1991). The Chortis block moved about 1050 km toward the east. This fact caused the truncation of the South Mexican continental margin. Migmatites of the Xolapa complex were intruded by plutonites between 35 Ma and 27 Ma. The age decreases from west to east, due to the movement of the Chortis block. Because of this eastward movement, the magmatic arc shifted to its present mid-Mexican position and the Xolapa complex was uplifted ( Meschede and Frisch, 1998). With the help of the moving magmatic activity the eastward directed velocity of the Chortis block was estimated at 56 mm/year. This is in a good agreement with opening rates of the Cayman Trough (Rosencrantz et al., 1988) and subduction rates at the Lesser Antilles subduction zone (Sykes et al., 1982).

### 2.1.2. THE SOUTHERN CARIBBEAN PLATE BOUNDARY ZONE

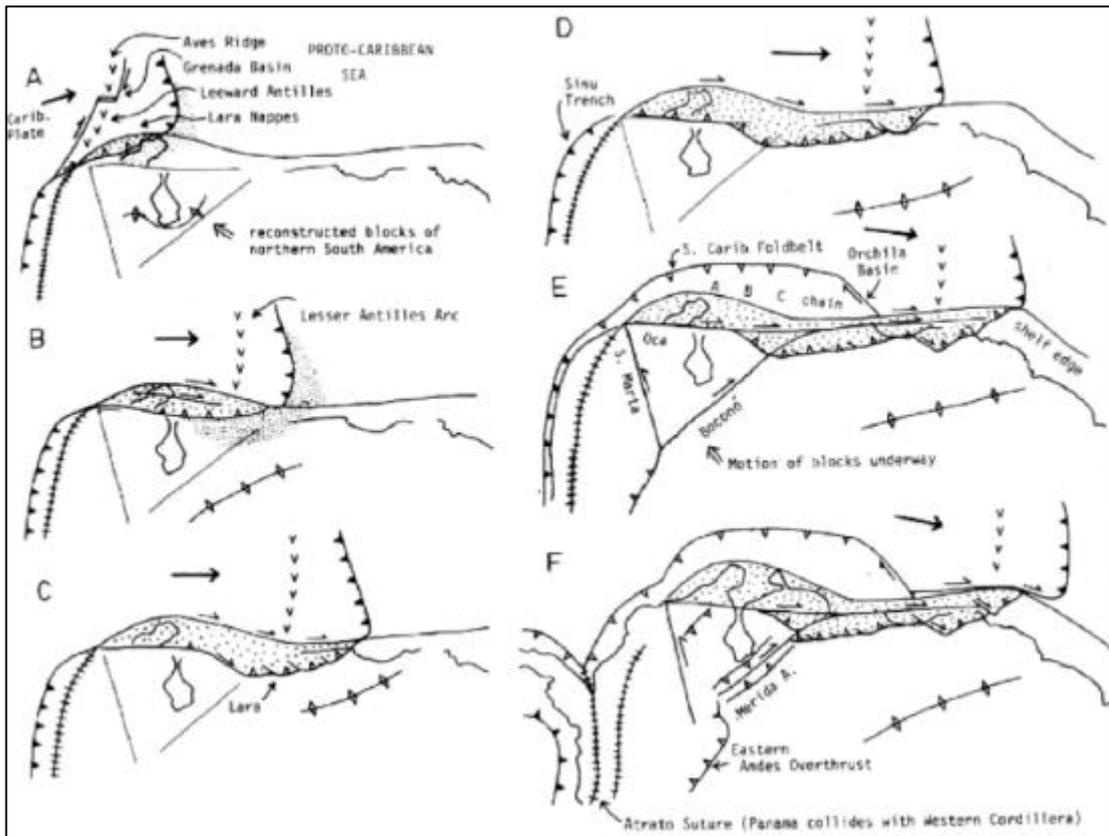
The Southern Caribbean plate boundary is a very complex zone of thrusting, transcurrent motion and rifting (Pindell and Barrett, 1990). Nappes on the Venezuelan foreland are getting younger in eastward direction caused by the eastward movement of the Caribbean plate. Palaeomagnetic data show clockwise rotation of some southern blocks along dextral



shear zones.

The Leeward Antilles were connected with the Aves ridge, but with the opening of the Grenada basin (GB, Figure 2) during the Palaeocene the Leeward Antilles moved away from the Aves ridge. Because of the compression between North America and South America a thrust zone developed in Miocene times pushing the Leeward Antilles on a more oceanic part of the Caribbean plate. Since that time, the Caribbean-South American transcurrent plate boundary north of the Leeward Antilles accommodating most of the strike-slip displacement, has been overthrust. This leads to the development of the South American accretionary fold belt. "This overthrusting may evolve into subduction in

the future, but it is as yet amagmatic.” (Pindell and Barrett, 1990). For more detailed information see Figure 4.



**Figure 4. Six-staged Cenozoic development of northern South America.**

**A: Palaeocene. Opening of the Grenada basin. B and C: Eocene and Oligocene. Development of nappes onto the Venezuelan margin due to the eastward movement of the Caribbean plate. D and E: Early and Late Miocene. Northward thrusting of the Leeward Antilles. Caribbean-South American transform boundary became convergent. F: Present. Continued convergence between Pacific and South American Plate. V means island arc volcanism. (Pindell and Barrett, 1990)**

## 2.2. DIFFERENT CRUSTAL PROVINCES

In the Caribbean area three major crustal types occur: 1) Crustal blocks with pre-Mesozoic basement, 2) continental Mesozoic and Cenozoic crust and 3) thickened oceanic crust, formed during the Middle Cretaceous. Pre-Mesozoic basement is situated in the pre-existent parts of North and South America and in the northern part of the Central American Landbridge (namely Southern Guatemala, Honduras, Nicaragua and the Nicaraguan Shelf). It consists mainly of metamorphic rocks, such as mica shists and gneisses.

The southern part of the landbridge is formed by primitive Mesozoic and Cenozoic magmatic arcs on the Caribbean crust as a result of the subduction of the Pacific plate beneath the Caribbean. In the south there are no crustal blocks with pre-Mesozoic basement. But this represents a problem within the Pacific Model of formation: If the Caribbean plate was formed within the Pacific, why is there no pre-Mesozoic basement in the southern part of this landbridge (see Fig. 6 and text below)? Also the other magmatic

arcs (Greater Antilles, Lesser Antilles etc.) consist of Mesozoic and Cenozoic rocks. Mesozoic and Cenozoic sandstones, siltstones and shales, occurring above the metamorphic basement, are the most in common rocks.

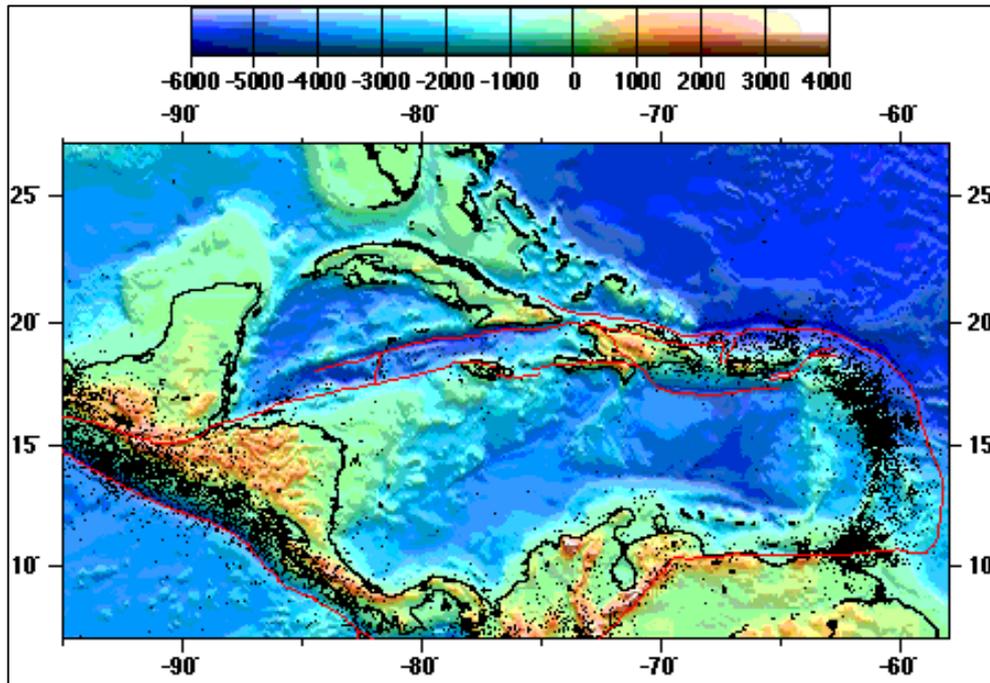
The main part of the Caribbean plate consists of thickened oceanic crust of a plateau basalt. It was formed mostly in the Middle Cretaceous. Geophysical investigations detected a B''-reflector and that was interpreted as the uppermost part of this thick oceanic crust. The existence of 15 to 20 km thick oceanic crust is one of the many unsolved problems of the Caribbean. Some authors speculate about a so called "superplume" event (Cox, 1991, Larson, 1991), but there is no direct evidence for such an event. Only geophysical data and age dating on obducted ophiolites, yielding Middle Cretaceous ages, support the assumption of a Middle Cretaceous thickened oceanic crust, but the creating process is still unknown. This could be a further goal for studies. The buoyant and stiffened oceanic crust is thought to be the reason for preventing subduction of the Caribbean plate beneath its surrounding areas.

### 2.3. GEOLOGICAL SETTING

Within the Caribbean plate it is possible to distinguish between subduction related magmatic rocks occurring in magmatic arcs, ocean basins with present formation of oceanic crust and major collision zones.

#### 2.3.1. MAGMATIC ARCS

There are nine magmatic arcs or pieces of arcs in the Caribbean region. The *Greater Antilles* represent island arcs with continental blocks yielding Late Proterozoic ages in some parts (Renne, et al., 1989). Cuba, Hispaniola, Puerto Rico and Virgin Island belong to that group of magmatic island arcs formed on oceanic crust. Subduction related magmatism occurred since the Middle Cretaceous to the Middle or Late Eocene. The *Aves Ridge* arc started its activity at the beginning of the Late Cretaceous and ceased in the Early Palaeocene. After that time a calcareous sedimentation took place on top of the arc. The *Sierra Maestra* arc was identified with an activity only during the Palaeogene (Stanek, 1998). The *Lesser Antilles* arc of the Eastern Caribbean started magmatism in the Oligocene. Eventually it was connected with the Aves ridge, but separated by intra-arc spreading during the Palaeogene, which generated the Grenada basin. Also the Late Cretaceous to Early Tertiary *Leeward Antilles* are thought to have been connected with the Aves ridge in former times. Along the north-western boundary of South America subduction related magmatism occurred at least since the Jurassic. The *Costa Rica-Panama* arc started its magmatic activity during Jurassic to Early Cretaceous, followed by primitive island-arc development in the Middle and Late Cretaceous. The *Chortis* arc, situated on Pre-Mesozoic crust, was active since the Late Jurassic and the *Nicaraguan Rise-Jamaica* arc at least since the Early Cretaceous. There is an obviously younging of magmatic activity in eastern direction, connected with the eastward movement of the Caribbean plate relative to North and South America. The cessation of subduction zones was mainly caused by the convergence between both Americas. The oldest magmatic activity is situated on the Central American Landbridge covered by the products of the present volcanic activity caused by the subduction of the Pacific plate beneath the landbridge. Earthquake activity is recorded near the Lesser Antilles, a recent subduction zone of the Atlantic Ocean beneath the Caribbean plate and at the Central American Landbridge. Both areas represent the still active parts of the subduction zones (Figure 5).



**Figure 5. Earthquake activity within the Caribbean region. There is an obviously concentration at the Lesser Antilles and the Central American Landbridge, both represent active subduction zones.**  
([www.fiu.edu/orgs/caribgeol](http://www.fiu.edu/orgs/caribgeol))

### 2.3.2. OCEAN BASINS

There are three ocean basin within the Caribbean Sea. All of them were formed mostly during the Cenozoic. The *Yucatan basin* is interpreted as a back-arc or intra-arc spreading system due to the subduction of oceanic crust beneath Cuba during its collision with the Bahama platform in the Palaeocene. Seafloor spreading occurred in the basin with NE-SW extension (Rosencrantz, 1990). The *Cayman Trough*, a pull-apart basin, marks the northern plate boundary of the Caribbean. It has a N-S extension of 100 km and an E-W extension of 1400 km. In the middle of the trough there is a spreading centre producing oceanic crust. Oldest sediments within the Cayman Trough show at least Early Cretaceous age (Leroy et al., 1996). The *Grenada basin* was formed by the separation of the Lesser Antilles from the Aves ridge during the Palaeocene and Eocene. It seems to be a pull-apart basin due to a dextral shear zone.

### 2.3.3. OROGENIC EVENTS CAUSED BY COLLISION

Five major collisional events have been identified within the Caribbean plate. The Greater Antilles collides with the southern part of the Bahama platform during the Late Palaeocene till the Middle Eocene. The effects of this collision decrease in eastern direction. At that time, the rocks of the arc and the fore arc were overthrust about 90 km upon the carbonatic platform of the Bahamas. As a result of this process, nappes and olistostromes developed. Subsequently the whole rock series were folded and sinistral tear faults developed. Younger sediments transgressed unconformably. There is a present convergence between Hispaniola and the South Bahama platform due to movements along

the Oriente fault. In the Late Cretaceous a terrane (possible part of the Chortis block) collided with the Maya complex forming the Motagua fault. A northward compression with a south facing subduction zone is assumed.

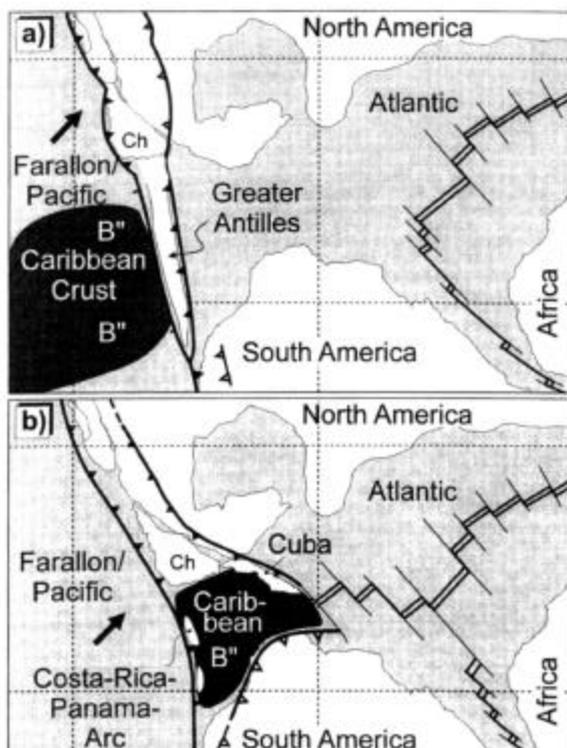
In the southern part of the Caribbean there was a development of nappes upon the Venezuelan foreland in the Cenozoic coming from the north or northwest. The rocks are typical for accretionary wedges of subduction zones, such as metamorphites, ultramafites, volcanogenic sandstones and shales and minor limestone. The nappes show a diachroneity toward the east. It is related to the eastward movement of the Caribbean plate. Because of the later strike-slip offsets the colliding magmatic arc is very difficult to identify, but it is thought that the Leeward Antilles were part of the assumed arc.

The Romeral Suture developed during the Latest Cretaceous due to the collision of the Western Cordillera oceanic complex with the Central Cordillera of Colombia. The result was this major fault dividing two distinct geological provinces. The eastern part is made of Precambrian to Cenozoic continental rocks of the Cordillera Central and the Santa Marta Massif, but the western part consists of Cretaceous oceanic crust, highly deformed deep-water sediments and magmatites of the Western Cordillera. An east-dipping subduction zone is proposed, which stepped back to the west after the collision (Pindell and Barrett, 1990). The Atrato Suture Zone developed as the result of the collision of the eastern part of the Costa Rica-Panama arc with the Western Cordillera during the Miocene. The present northward convexity of the arc is a result of its northward escape into the Colombian basin due to the collision. The closure of the connection between the Caribbean and the Pacific is marked by a differentiation of planktonic species, the beginning of a faunal exchange between North and South America and the cease of chert deposition in the Caribbean Sea due to the end of the deep-water circulation

All these “orogenic events” show an eastward movement of the Caribbean plate relative to the Americas. In the following I want to discuss two models of how the Caribbean might have formed.

### 3. DIFFERENT MODELS OF FORMATION OF THE CARIBBEAN

#### 3.1. GENERAL INFORMATION



There are nearly as many different models of formation and origin of the Caribbean plate as terranes are involved in the development of this region. And the discussion about it is still going on. The situation in Pre-Jurassic times is nearly unsolved due to disagreements in using references for reconstruction (1000m isobaths, palaeomagnetic poles or realignment of marginal offsets). But there are at least two different models starting in Jurassic times (see Figure 6). The first model is named the Pacific model. It is preferred for example by Pindell and Barrett (1990). It suggests a Late Mesozoic origin of the Caribbean plate within the Pacific Ocean. Later it drifted away from its former position as an

allochthonous part now situated between the two Americas. The Galapagos hotspot is supposed to be the reason for the thickened oceanic crust. The Alternative model suggests the formation of the Caribbean plate between North and South America at a more western position as today. Both models agree since the beginning of the Cenozoic. Difficulties and problems of these hypotheses are discussed below.

**Figure 6. Two different hypotheses of the origin of the Caribbean plate. a, "Pacific model" b, Alternative hypotheses as intra-American position (Meschede and Frisch, 1998)**

### 3.2. PACIFIC MODEL

The supporter of this model assume a rifting and a beginning separation of North America, Yucatan, the Bahamas and South America during the Middle Jurassic until the Late Jurassic. Then the Pacific Model creates the Caribbean plate within the Pacific plate during the Cretaceous, eventually as the result of the Galapagos hotspot. After its formation in the Cretaceous it is moved toward the east into the pre-existent Proto Caribbean Basin along major strike-slip fault systems. During the Latest Jurassic and the Late Cretaceous or the Earliest Tertiary they suppose the development of passive margins at the Bahama platform, Yucatan and the northernmost part of South America, whereas the Proto Caribbean Basin widens due to its drift between North and South America. From the Eocene until recent times major strike-slip fault systems developed at the northern and southern boundaries of the Caribbean plate as a result of the eastward movement of the plate with respect to the Americas. Another result of that movement is an "orogenesis" around the Caribbean lasting until now. The last step of the development is a Miocene till recent deformation occurring within the Caribbean region, the so called Neo-Caribbean phase of deformation. It is caused by the convergence between North and South America, the north-eastern migration of the Andean terranes in direction to northwest South America and the convergence occurring in Hispaniola discussed above. After the presentation of the Alternative model I want to make a comparison between the two different models and to show some inconsistencies in the Pacific model.

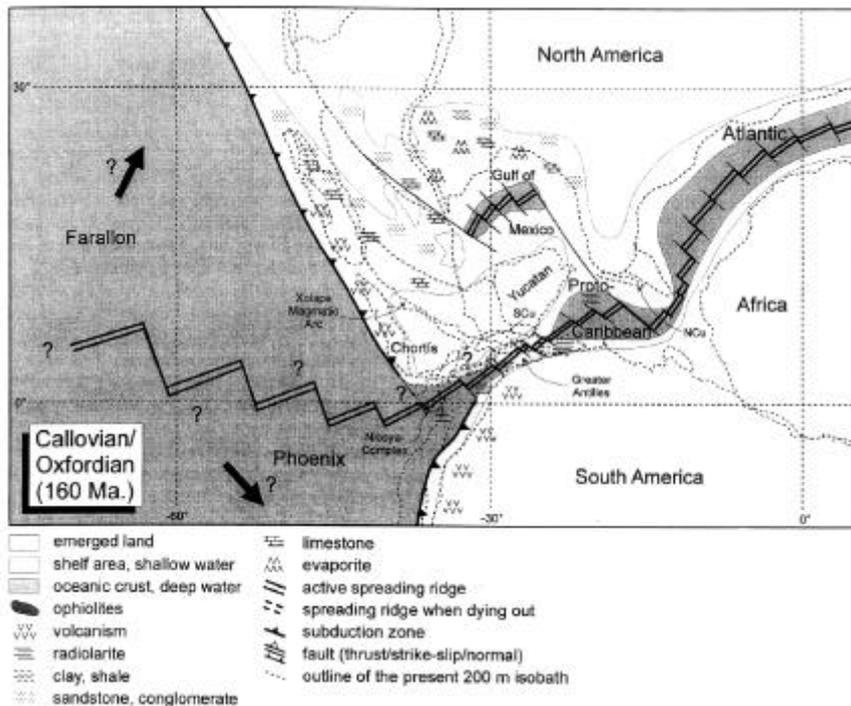
### 3.3. ALTERNATIVE MODEL

An Alternative model was proposed by Meschede and Frisch (1998). They suppose the origin of the Caribbean plate not within the Pacific plate, but as an intra-plate realm between North and South America with following eastward movement.

#### 3.3.1. MIDDLE TO LATE JURASSIC

During the Callovian and Oxfordian, about 160 Ma ago (Figure 7), they assume a spreading axis trending NE-SW. This axis propagates in the east in the direction of the Central Atlantic and the Penninic Ocean and toward the west toward the spreading centre between the Farallon and the Phoenix plate. The opening of the Gulf of Mexico took place at the same time. They assumed, that the Nicoya Complex, a complex of oceanic crust in Costa Rica, was situated at the spreading centre between the Americas and thus, near the equator, as derived from palaeomagnetic results. This is a direct antithesis to Pindell and Barrett (1990). They declared the Nicoya Complex as related to the Farallon plate (or therefore the Phoenix plate) lying at about 30° to 40° S. Mafic rocks occurring on Cuba

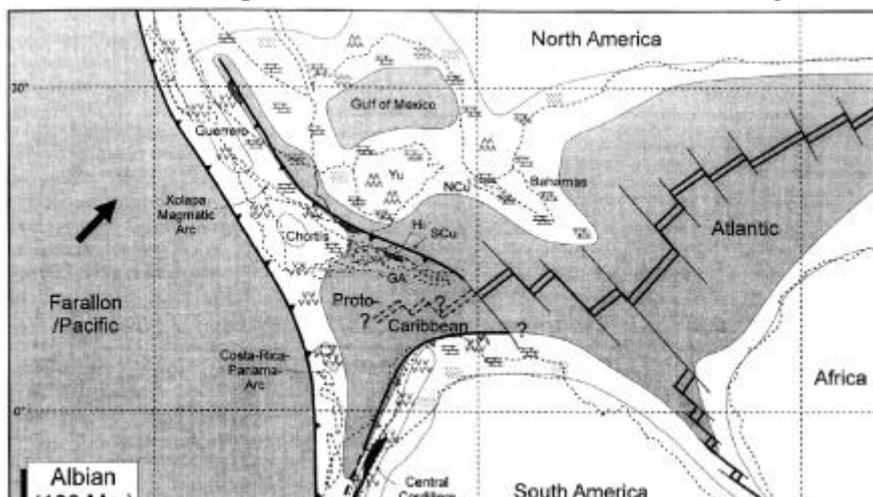
yield ages of about 160 Ma. These rocks thought to be the oceanic basement of an island arc at this time, later incorporated into the accretionary prism. This mafic rocks are interpreted as parts of the Proto-Caribbean plate occurring at this time nearby the equator (see figure 10 and text below).



**Figure 7. Callovian/Oxfordian reconstruction of the Caribbean region (Meschede and Frisch, 1998)**

### 3.3.2. EARLY TO MIDDLE CRETACEOUS

During the Early and the Middle Cretaceous the Proto Caribbean Sea opened between the divergent plates of North and South America. The beginning of an arc activity is dated within the Middle Cretaceous due to the development of subduction zones in the north-eastern and southern parts of the Caribbean (Figure 8). A southwest dipping Greater Antilles intra-oceanic subduction zone (Figure 8) is inferred with the help of a southwest dipping thrust zone in this area. The Guerrero block, the Greater Antilles and the ophiolitic rocks of the Motagua-Polochic fault system show similar magmatic and sedimentary evolution at this time. Also the Costa Rica-Panama arc was existent with the beginning of the Albian. There are Campanian andesitic volcanics covered by recent volcanism in the eastern part of Costa Rica and Southern Nicaragua. In the Middle



**Figure 8. Albian reconstruction of the Caribbean region (Meschede and Frisch, 1998)**

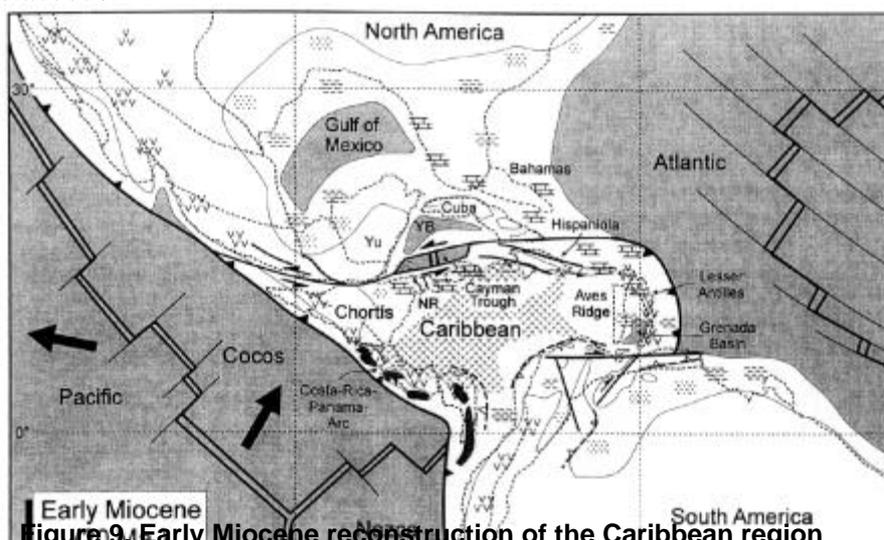
Cretaceous, between Albian and Campanian, they suppose the formation of the plateau basalts and the thickening of the oceanic crust to about 15 km or 20 km. The covered area is comparable with the Ontong-Java-Plateau within the Southwest Pacific (Coffin and Eldholm, 1994). It is related to an assumed Middle Cretaceous “superplume” event (Cox, 1991).

### 3.3.3. LATE CRETACEOUS

With the opening of the South Atlantic and the thereby caused convergence between North and South America, seafloor spreading stopped in the Caribbean plate in Santonian times. Another reason for the termination of the spreading could be the thickened oceanic crust. The recent volcanic arcs developed in the eastern and western part of the Caribbean. At the northern boundary a southwest dipping subduction zone is assumed to be active between the Late Cretaceous and the Palaeogene. This caused the north-eastward movement of the Cuban island arc and the following closure of a small ocean between Cuba and the Bahama platform. Because of this compressional event ophiolites have been thrust upon sediments of the Bahama platform in the northern part of Cuba. The final collision took place in the Early Palaeocene and therefore the Cuban block became part the North American plate. Within the Campanian (70 Ma) the direction of movement of the Farallon plate changes from northeast to east. This caused a little convergence between the both Americas.

### 3.3.4. TERTIARY TO RECENT TIMES

Today North and South America move in westward direction with velocities between 3,0 and 3,3 cm/year. This process has been started already in the Latest Cretaceous. The Caribbean plate also moves toward the west, but with a lower speed of about 1,9 cm/year. This causes a relative eastward movement of the Caribbean with respect to the Americas. With the assumed velocities, there is an offset of at least 1000 km starting within the Latest Cretaceous.



**Figure 9. Early Miocene reconstruction of the Caribbean region**

The Yucatan basin between Cuba, Yucatan and Hispaniola opened at the beginning of the Cenozoic. It is interpreted as a back-arc or intra-arc spreading system due to the subduction of oceanic crust beneath Cuba during its collision with the Bahama platform. The opening of the Cayman Trough is the result of the development of a pull-apart basin at the Motagua-Polochic fault system. Along this sinistral strike-slip fault the Chortis block moved toward the east related to the movement of the Caribbean plate. The Grenada basin opened during the Palaeocene and Eocene due to the separation of the Lesser Antilles from the Aves ridge.

The Farallon plate changes its moving direction again back to northeast. This fact is also reflected in the palaeostress fields of Southern Mexico. During the Late Oligocene and the Early Miocene the Farallon plate splits into the northern Cocos plate and the southern Nasca plate. The Cocos plate drifts north-northeast and the Nasca plate moves in eastern direction (Figure 9).

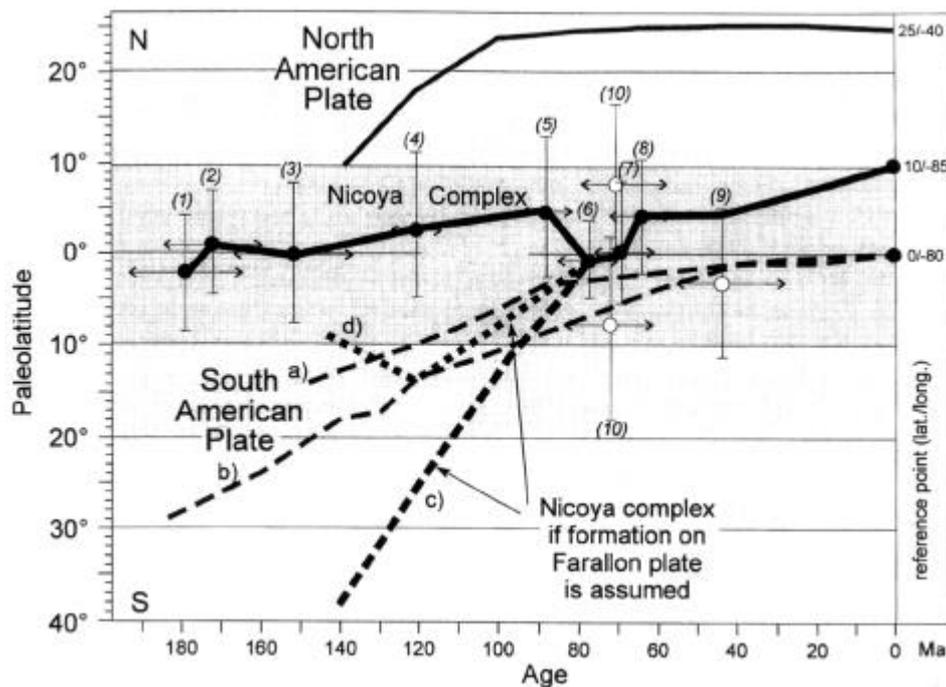
Due to the continuous westward movement of the South American plate the Costa Rica-Panama arc collides with the Western Cordillera of Colombia during the Miocene. Its following northward escape causes the recent convexity of the arc in northern direction.

The movements of the involved plates are still going on and therefore the shape of this region will change in future times.

#### **4. DISCUSSION AND COMPARISON OF THE BOTH MODELS**

During the 1990's the Pacific model was the standard model. It shows inconsistencies in its explanation of the Caribbean plate. At least some of them are discussed subsequently. The first problem is the distribution of land and sea during the Jurassic. Mainly the Nicoya Complex is hardly discussed. The Pacific model suggests that the Nicoya complex was formed within the Pacific plate at about 40° S and therefore it should yield palaeomagnetic data showing the movement of the Pacific plate. Both models predicted the complex was close to the equator at about 80 Ma ago. According to the Pacific Model,

the complex had to move about 40° northward during the Early Cretaceous to reach its Middle Cretaceous position. However, the ophiolites belonging to the Nicoya complex show only a movement of about 10°. So how should the complex come to its position?



**Figure 10. Palaolatitudes of ophiolitic complexes in Northwest Costa Rica (Meschede and Frisch, 1998)**

The northward movement of only 10° latitude is closely related to the movement of the South American plate.

Another aspect of the Pacific model is the question of space between the both Americas at the beginning or during the Mesozoic. They assumed not enough space between North and South America to create the Caribbean plate there. New data for the Hauterivian inferred enough space for a narrow 120 x 150 km ocean basin with assumed spreading rates of only 0,4 to 0,5 cm/year.

The Pacific model relates the thickened oceanic crust to the Galapagos hotspot within the Pacific plate due to comparable isotope signature. But the oldest rocks occurring at the Galapagos hotspot yield Miocene ages and the youngest rocks of the Caribbean yield Late Cretaceous ages. Therefore the hotspot had to be inactive for about 40 to 50 Ma. This and the fact of the recent convergence of the eastward moving hotspot and the westward moving Caribbean plate cause rates of divergent movement during the Late Cretaceous of about 25 cm/year to reach the present distance. These rates are absolutely unrealistic. After Wilson (1989) the ophiolites, obducted around the Caribbean, show intra-plate and Mid-Ocean-Ridge type basalts. Therefore the isotopic comparability is no evidence for the formation at the Galapagos hotspot.

Also the existence of the Costa Rica-Panama arc at Albian times cannot be explained by the Pacific Model.

The worst problem of the Alternative model is the existence of the thickened oceanic crust. There are no clear reports of how it might have formed or what the creating process

was. The Pacific model gives an explanation for this problem. If the formation at the Galapagos hotspot is possible has to be studied further.

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