Beleg-Exemplar

Zbl. Geol. Paläont. Teil I	199[redacted]	H. [redacted]	[redacted]--[redacted]	Stuttgart, [redacted]

3 112

Model of Meso-Cenozoic evolution of the northwestern Caribbean

By K.-P. STANEK and S. VOIGT, Freiberg/Sa.

With 7 figures in the text

STANEK, K.-P. & VOIGT, S. (1993): Model of Meso-Cenozoic evolution of the northwestern Caribbean. - Zbl. Geol. Paläont. Teil I, **1993** (1/2): 499-5xx; Stuttgart.

Abstract: Due to the convergent plate movements of the Pacific Farallon plate and the western margin of Pangea, a double rift system, connected by NW trending transform faults, developed in the Early and Middle Jurassic. During the Late Jurassic, new oceanic crust began to form both in the Gulf of Mexico and in the Proto-Caribbean. In the Neocomian, the Great Antillean island arc was generated between Chortis and South America. In the Middle Cretaceous, the petrochemistry and type of island arc magmatism changed, as the westernmost part of the arc presumably collided with Yucatan. At the end of the Late Cretaceous, the obduction of the Cretaceous island arc onto the Bahama platform started; due to the reversal of subduction polarity, a Tertiary island arc was formed to the south. From the Late Eocene, the Polochic-Motagua-Cayman transform fault was activated; the subduction along the Tertiary arc stopped and the Yucatan basin was separated from the Caribbean plate.

Zusammenfassung: Hervorgerufen durch konvergente Plattenbewegungen der pazifischen Farallon-Platte und der westlichen Pangäa entwickelte sich im unteren und mittleren Jura ein doppeltes Riftsystem, welches über NW streichende Transformstörungen verbunden ist. Im oberen Jura beginnt sowohl im Golf von Mexiko als auch in der Proto-Karibik die Neubildung ozeanischer Kruste. Im Neokom kommt es zwischen Chortis und NW-Südamerika zur Anlage des Großen Antillen-Inselbogens. In der mittleren Kreide ändern sich Petrochemie und Charakter des Magmatismus im Inselbogen, der Westteil des Bogens kollidiert vermutlich mit dem Südrand von Yucatan. Am Ende der Oberkreide beginnt die Obduktion des kretazischen Inselbogens auf die Bahama-Plattform, durch die Inversion der Subduktionsrichtung bildet sich der tertiäre Inselbogen in den östlichen Großen Antillen. Ab dem oberen Eozän wird die Polochic-Motagua-Cayman-Transformstörung aktiviert, die Subduktion im tertiären Bogen endet, und das Yucatanbecken wird von der Karibischen Platte getrennt.

Resumen: En el margen oeste de Pangea, un doble sistema de rift continental se desarrollo por los movimientos convergentes de las placas Farallon y Pangea durante el Jurásico Inferior y Medio. En el Jurásico Superior tanto en el Golfo de México como en el Protocaribe la formación de una corteza oceánica nueva comenzó. En el Neocomiano el arco insular de Antillas Mayores se ha generado entre América del Sur y el bloque Cortis. En el Cretácico Medio el carácter y la petroquímica del magmatismo del arco insular gambió, la parte oeste del arco probablemente chocó con el margin sur de Yucatán. Al final del Cretácico Superior la obducción del arco insular Cretácico por encima de la plataforma Bahámica inicio. Por la inversión de la polaridad de la subducción, el arco insular Terciario se formó en el sur y en la parte oeste de los Antillas Mayores. A partir del Eoceno Superior la zona de falla Polochic-Motagua-Caymán fue activada. La subducción en el arco Terciario terminý y la cuenca marina de Yucatán quedó separado de la placa Caribena.

Introduction

The Meso-Cenozoic geotectonics of the northwestern Caribbean are mainly based on the geological data of Cuba and adjacent areas. Different geotectonic concepts, different points of view in terrane-partitioning, and the sparseness of available modern Cuban data result in a wide spectrum of geotectonic models (PINDELL & DEWEY 1982, ANDERSON & SCHMIDT 1983, RJABUCHIN et al. 1983, ROSS & SCOTESE 1988, STEPHAN et al. 1990).

This paper combines systematic analyses of the stratigraphic and magmatic development of the Cuban part of the Bahama platform and the Cretaceous-Tertiary, north Caribbean island arcs with regional plate kinematics, to propose a modified model of rifting, island-arc evolution and arc-continent collision.

The paleomagnetic reference frame contained in the software of the ATLAS Program (GR6P) by the Cambridge Paleomap Service was used for rotational poles and the continental framework (North America-NAM, South America-SAM, Africa) of the developing oceanic Caribbean microplate. The velocity vectors of the Pacific Farallon plate are given by ENGEBRETSON et al. (1985). Geochronological data are taken from the Global Stratigraphic Chart (IUGS 1989). Although the paleogeographic positions of the continental framework can be well reconstructed using the magnetic anomalies of the Atlantic, the geologic development of the Central American - Caribbean domain remains problematical. We tentatively chose a system of only three continental blocks for the pre-breakup position of Chortis, Mexico and Yucatan, with respect to the available geological data of Early Mesozoic rift-related sedimentary and igneous rocks. Still unsolved is the gap between Chortis and Baja California.

The seven stages from Middle Jurassic to Early Tertiary (Figs. 1-7) show the important geological events in the history of the northwestern Caribbean, ending with the separation of the Yucatan basin and the Cuban orogenic chain from the Caribbean plate by the activation of the Cayman-Bartlett fault zone.

Paleogeographic reconstruction

The starting point of our reconstruction is the completely closed Pangea. Subduction occurred at the western active margin of Pangea since the Jurassic. The stretched continental crust of the recent Bahama platform, part of the former Florida Straits block, has been restored to its original dimension and fitted against West Africa. The northernmost part of Cuba is now underlain by Bahama-type crust, exposed in small outcrops of metamorphic rocks in northern Las Villas, central Cuba (SOMIN & MILLAN 1981). Northwestern SAM has been moved sinistrally along the Boconó Fault to the SW. The Chortis block has been restored to the west against the strike-slip offset of the Polochic-Motagua Fault Zone (PMFZ).

The continental rifting of western Pangea started in the Early Jurassic as a result of passive transtension due to the rigid behaviour of the continental plate, caused by oblique plate convergence of the Pacific Farallon and Pangea.

Crustal thinning and rifting propagated along a NW-SE trending transform fault (Mojave Sonora Megashear-MSM) from the Pacific coast into the Gulf of Mexico and the Florida panhandle, and assumedly to the east coast of NAM (Brunswick Magnetic Anomaly). In the south, the Proto-Caribbean rift evolved from the Pacific between northwestern SAM and the Chortis-Mexico-Yucatan blocks to the southwestern edge of the Florida Straits block.

The presumably most comprehensive stratigraphic sections of the early rifting stage of the Proto-Caribbean rift can be expected in NW-SAM (GEYER 1973), the eastern part of the Yucatan Peninsula and Pinar del Rio in western Cuba (HASZEWSKI 1976), comprising taphrogenic red beds and locally rift-related magmatites of the San Cayetano Formation.

165 Ma (Fig. 1): Between 180 and 175 Ma, the northern rift axis of the Proto-Atlantic "jumped" from the Brunswick Magnetic Anomaly to the Blake Spur Anomaly (GROW & SHERIDAN 1981) along the North Bahama Transform Fault (NBT), so that the Gulf of Mexico is bounded by two transform faults. At this time, the Gulf of Mexico area and the Florida Straits Block underwent crustal stretching by thermal subsidence, related at the surface to the accumulation of red beds, felsic volcano-clastics and deposition of evaporitic formations (Louann Salt, Punta Alegre formation). At the beginning of the Late Jurassic (around 150 Ma, BUFFLER et al. 1981), spreading and the formation of new oceanic crust started in the Golf of Mexico. Approximately at the same time (Middle to Late Oxfordian), the sedimentary facies of the evolving, east Yucatan continental slope (Pinar del Rio in westernmost Cuba) changed from terrigenous clastic and shallow marine to pelagic carbonates in the Sierra de los Organos (PSZCZOLKOSKI 1975), and from terrigenous to shallow marine carbonates along the former shore line, now the Esperanza zone (RODRIGUEZ 1987). In the whole area, the facies change was accompanied by the extrusion of basic volcanics and related massive sulfide deposits (JÄGER 1972). According to these data, the spreading both in the Gulf of Mexico and in the Proto-Caribbean started nearly simultaneously.

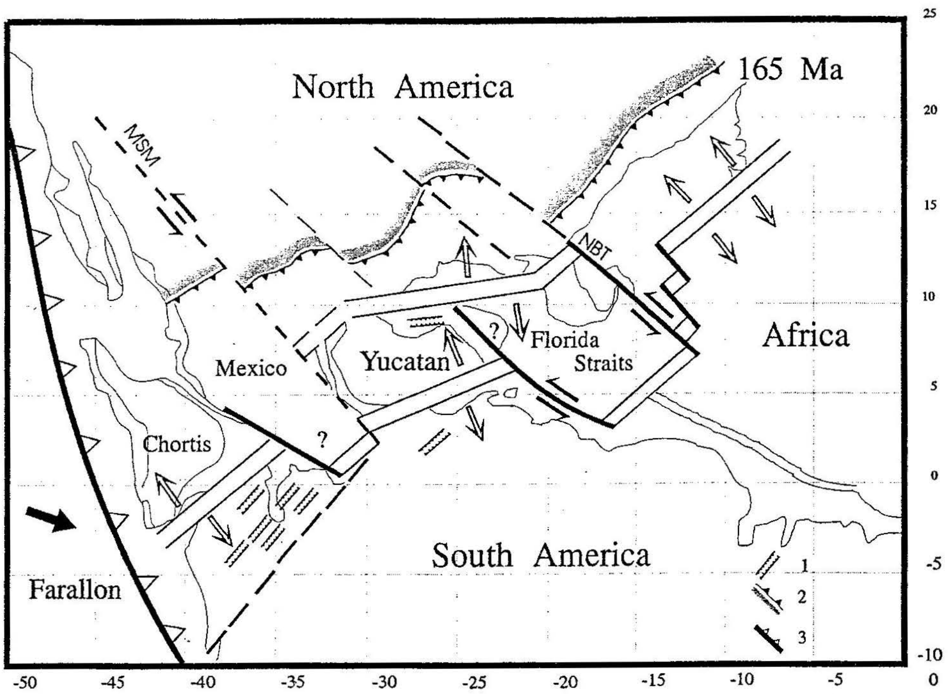

Fig. 1. Paleogeographic reconstruction for the Middle Jurassic (165 Ma). MSM - Mojave-Sonora Megashear, NBT - North Bahama Transform Fault; 1 - rift-related graben structures, 2 - front of the Appalachian orogen, 3 - subduction zones.

At the Middle/Late Jurassic boundary, the eastern Yucatan and northwestern SAM became passive rift margins.

140 Ma (Fig. 2): The generation of oceanic crust in the Gulf of Mexico stopped in the Late Jurassic at 145 Ma (ROSS & SCOTESE 1988). The Mojave-Sonora Megashear and the North Bahama Transform Fault remained inactive, the Gulf basin and the Chortis-Mexico-Yucatan-Florida Straits block became part of the North American plate. The Florida Straits block attained maximum final extension (FREEMAN-LYNDE & RYAN 1987). The now separated andinotype subduction zones of the western margin of Laurasia and Gondwana were linked by a postulated transform fault.

Comparing the sedimentary facies and starting time of sediment accumulation within the northwestern Proto-Caribbean rift, there are strong indications for different types of continental margins. In the west, along the eastern margin of Yucatan, a passive continental margin existed with rift-related terrigenous clastic and subordinate vulcanogenic sequences from Early to Middle/Late Jurassic (San Cayetano Formation) and marine carbonate series from Upper Jurassic to Cenomanian. This development also comprises the metamorphosed sediments and volcanites of the Escam-

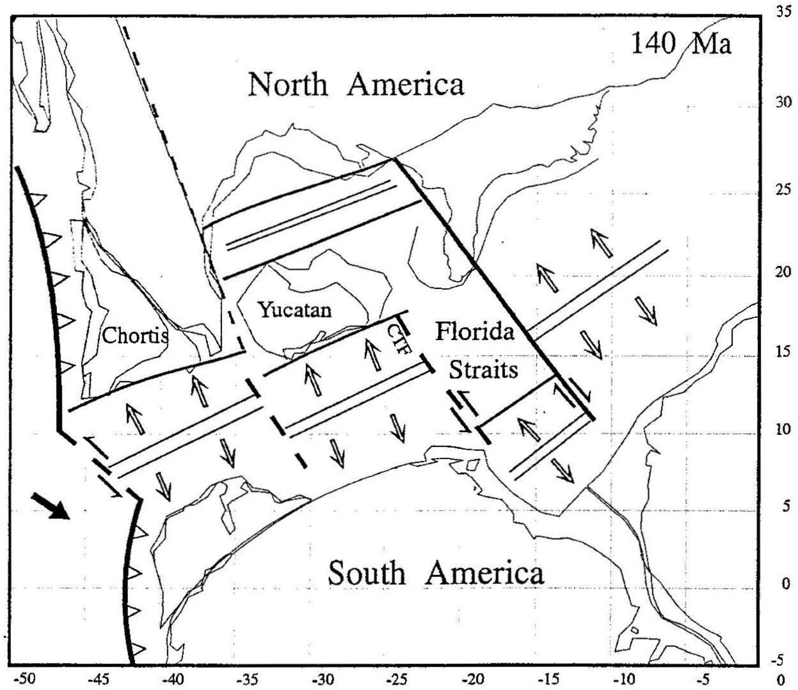

Fig. 2. Paleogeographic reconstruction for the Late Jurassic (140 Ma). CTF - Cuba Transform Fault.

bray (MILLAN & MYCZYNSKI 1978, DUBLAN & ALVAREZ et al. 1986) and the Isla de Juventud (Pinos).

In the north, along the Cuban Transform Fault (CTF), the southern edge of the Florida Straits Block, a continental scarp developed with small amounts of pelagic limestones, cherts and locally interlayering volcanics (KANCHEV et al. 1978, ITURRALDE-VINENT & MARI 1988) from Tithonian to Cenomanian. On the northerly situated Florida Straits Block a shallow-marine carbonate platform was deposited after the Tithonian, resting on the metamorphic-magmatic basement (PSZCZOLKOWSKI 1986). The carbonate platform represents a complete stratigraphic sequence of shallow marine deposits up to the Maastrichtian in the area of northern Cuba, the so-called Remedios zone. Only in eastern central Cuba, in the Sierra de Cubitas, do laminated and turbiditic limestones prove a deep marine environment during the Cenomanian and the Turonian (ITURRALDE-VINENT & THIEKE et al. 1987).

125 Ma (Fig. 3): Due to rotation of the spreading direction of the Farallon plate and the opening of the South Atlantic, a south-dipping subduction zone was generated along the postulated transform fault between Chortis and SAM, consuming newly-formed Proto-Caribbean oceanic crust. The first magmatic products of the evolving island arc (the later Greater Antillean Arc - GAA) comprised bimodal igneous rocks of basic

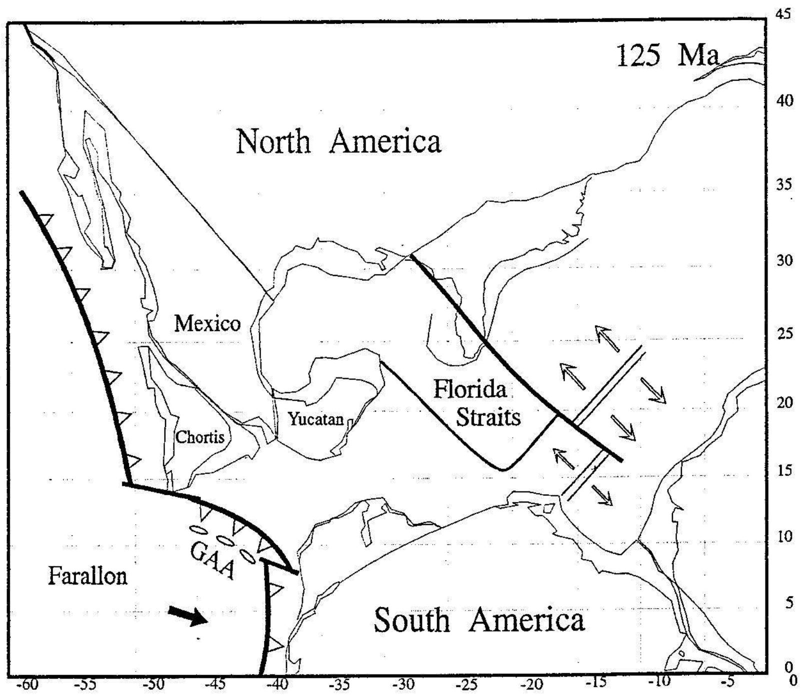

Fig. 3. Paleogeographic reconstruction for the Early Cretaceous (125 Ma). GAA - Great Antillean Arc.

and plagiorhyolitic vulcanites and related plutonites, plagiogranites and gabbrodiorites. These igneous rocks, exposed throughout the Greater Antillean islands from Las Villas and Camagüey in central Cuba (STANEK & CABRERA 1992) to Hispaniola and Puerto Rico, can be correlated with the PIA volcanics (DONNELLY & ROGERS 1980) and probably are of Neocomian age. According to this model, the basement of the island arc consisted of Pacific ocean crust of Upper Jurassic to Lower Cretaceous age, indicated by rare paleontological (ZELEPUGUIN et al. 1986) and geochronological data (SOMIN & MILLAN 1981).

95 Ma (Fig. 4): During the Early Cretaceous, the GAA was moving northeastward, producing calc-alkaline basaltoandesitic, mainly submarine volcanites. At Middle Cretaceous time, there were some breaks in the geologic development both of the island arc and the continental margins. The sediment accumulation at the continental slopes east of Yucatan (western Cuba) and along the continental scarp south of the Florida Straits block (northern Cuba) stopped; the carbonates and cherts of the latter show a notable input of fine igneous detritus. As mentioned above, deep marine limestones of the Bahama platform are evidence for temporary subsidence. The ceasing of sedimentation is assumedly due to the involvement of this region in the subduction zone and the accretionary wedge.

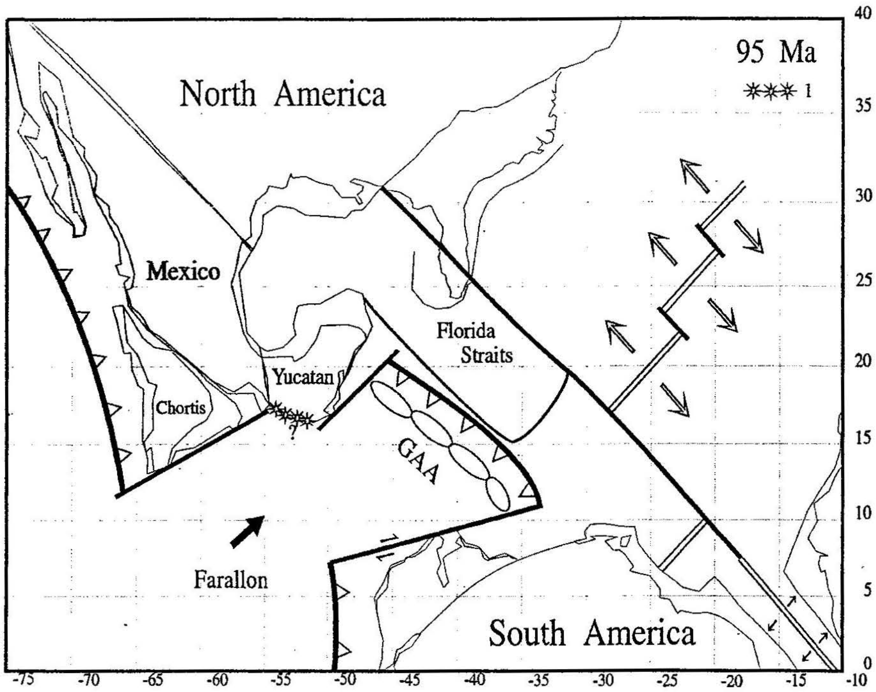

Fig. 4. Paleogeographic reconstruction for the Middle Cretaceous (Cenomanian - 95 Ma). 1 - collisional front.

Petrographic data on the island arc suggest that the changed subduction conditions resulted in a temporary change in magmatism. During Albian/Cenomanian, the island arc was being uplifted, marked by shallow marine carbonate and volcano-sedimentary sequences. Alkaline volcanism and plutonism occurred in central Cuba as syenitic intrusions and shoshonitic flows (ITURRALDE-VINENT & THIEKE et al. 1987) and in Puerto Rico (JOLLY 1971).

There are some indications for a collisional event in the Polochic-Motagua Fault Zone (PMFZ) (PERFIT & HEEZEN 1978), but up to now the problem of the origin and age of the El Tambor Formation, including the offset by the PMFZ is still unresolved. So the Late Cretaceous collisional event of the westernmost part of the GAA with the southern margin of Yucatan follows as a consequence from our model and is still unproved.

80 Ma (Fig. 5): During the Late Cretaceous, the uplifting island arc was undergoing erosion, and the volcanic activity decreased. By contrast, plutonic activity reached a climax in the Campanian. The western GAA collided with the Bahama platform, and the island arc started to thrust onto the platform, forming the Cuban ophiolite belt and affecting the carbonate sequences by northeastward folding. Island-arc-related magmatism ceased with the intrusion of small stocks of biotite granites and

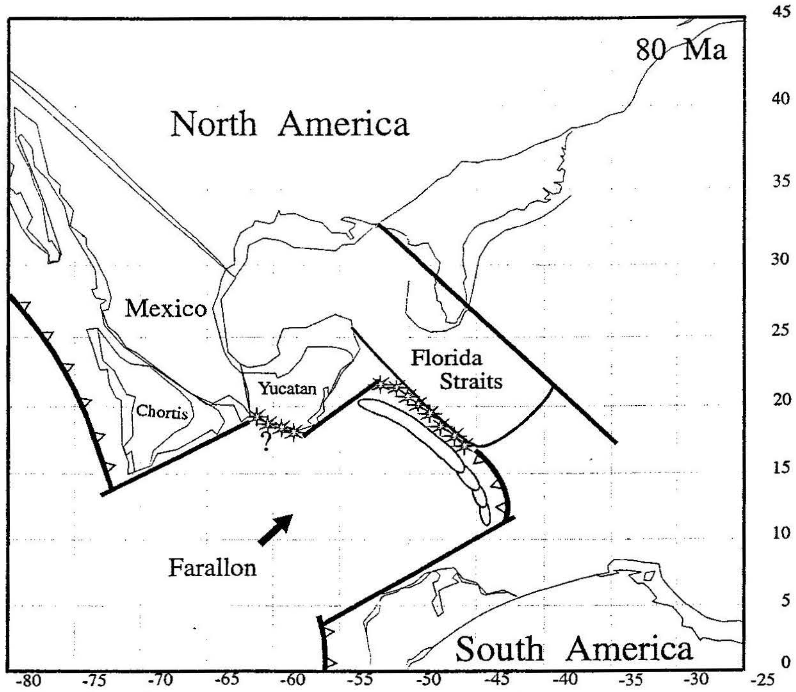

Fig. 5. Paleogeographic reconstruction for the Late Cretaceous (80 Ma).

rhyolitic necks. The WNW trending thrust zone was offset by systems of NE trending fault zones, which controlled the later block tectonics of Cuba. In the westernmost part of Cuba, in the Bahia Honda area, the so-called Bahia Honda unit (MOSSAKOWSKI & ALBEAR 1979) was being accumulated as a foreland deposit, resting unconformably on Jurassic/Early Cretaceous sediments of the Esperanza zone (SEGURA SOTO et al. 1985). The unit consists of an inverse sequence of ophiolite and island arc debris, interlayered with Late Cretaceous and covered by Early Tertiary clastic sediments (STANEK & MONTENEGRO, unpubl. data). Therefore, the Bahio Honda unit is not a terrane in the sense of HATTEN et al. (1988) and we do not need an oceanic rift between Yucatan and the Florida Straits Block (PIOTROWSKA 1993) to explain the existence of ophiolitic rocks in this structural position.

The arc-continent collision can be correlated temporally with the Santonian-Campanian "sill event" in the Proto-Caribbean (DONNELLY 1989).

60 Ma (Fig. 6): Due to the thrusting of the Cretaceous island arc, the Central Cuban Thrust was formed. The continuous NE movement of the Farallon plate provoked a reversal or "flip" of the subduction zone in the back-arc area. The new northward dipping zone is indicated by the structural and magmatic trends of the Sierra Maestra (Oriente province of eastern Cuba), representing the Tertiary island arc. The island

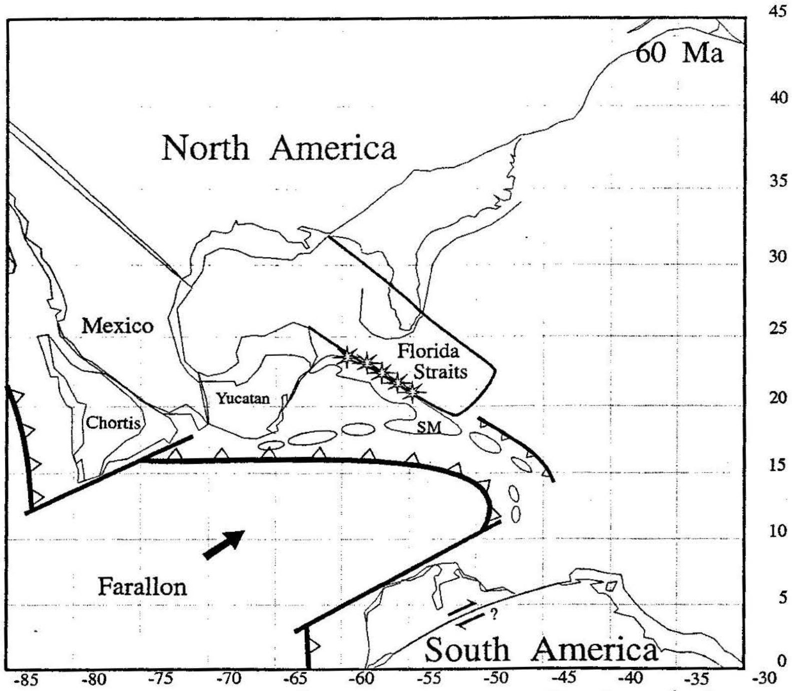

Fig. 6. Paleogeographic reconstruction for the Early Tertiary (Paleocene - 60 Ma). SM - Sierra Maestra mountains in eastern Cuba.

arc extended from the Sierra Maestra in Cuba to the east to Puerto Rico (and to the Aves Ridge?). The newly-formed arc was the focus of magmatic activity from Paleocene up to the Middle Eocene. We suggest that the Cayman ridge was the western prolongation of this Tertiary island arc (ROSENCRANTZ 1990). Comparing the Tertiary and the Cretaceous arc, there are some metallogenic differences with respect to the stratiform manganese deposits of the first one. In the back-arc area of central and western Cuba, the metamorphic complexes of the Escambray and the Isla de Juventud, comprising Jurassic to Lower Cretaceous metasediments and metavolcanics, were being uplifted. Geochronological data indicate a final stage of HP/LT-metamorphism during the Paleocene (SOMIN et al. 1992).

With the start of subduction in the Tertiary arc, the Yucatan basin, consisting of probable Jurassic oceanic crust of the preexisting Farallon plate, became a permanent part of the NAM plate.

38-40 Ma (Fig. 7): The direction of movement of the Farallon plated changed to nearly eastward, and the velocity vector of SAM increased with respect to NAM, both producing a major plate reorganization. At the northern and southern margins of the Caribbean, systems of E-W trending transform faults were formed. Through the generation of east- and west-dipping subduction zones in Central America and the Lesser

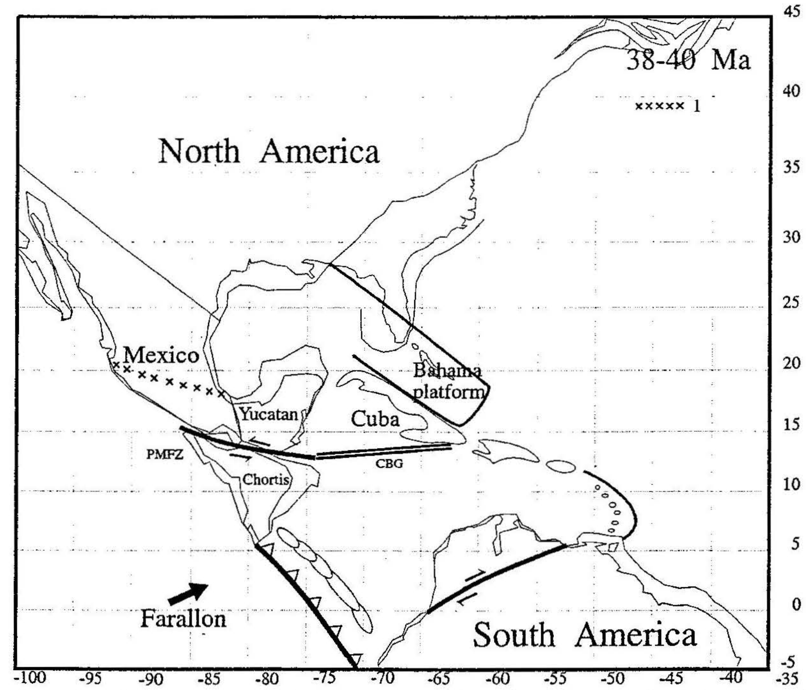

Fig. 7. Paleogeographic reconstruction for the Early Tertiary (Late Eocene - 38-40 Ma). PMFZ - Polochic-Motagua Fault Zone; CBG - Cayman-Bartlett Graben; 1 - indicates the trend of the Central Mexican Volcanic Belt.

Antilles, respectively, the Caribbean microplate became tectonically inactive. Along the northern Polochic-Motagua Fault, the Chortis block was shifted to the east (BURKART et al. 1987). Passive rifting took place in the Cayman trench (ROSENCRANTZ et al. 1988). Becausė of this transtensional movement, Hispaniola and Puerto Rico were separated by strike-slip faults, extending from the Cayman-Bartlett trench to the east and dividing the islands into four tectonic slivers.

Conclusions

(1) During the Early Jurassic, continental rifting started in two separated zones, in the Gulf of Mexico and the Proto-Caribbean. The formation of oceanic crust started in both basins approximately at the beginning of the Late Jurassic. Two types of continental slopes developed in the northwestern Proto-Caribbean: (a) the rift-related continental margin east of Yucatan, with continuous sedimentation during Jurassic and Early Cretaceous; and (b) the fault scarp related to the Cuban Fracture zone, with limited sediment accumulation from Tithonian to Cenomanian, forming the southern boundary of the Florida Straits Block.

(2) The Cretaceous island-arc evolution of the GAA started along a suggested transform fault between SAM and Chortis in the Early Cretaceous (Neocomian?), consuming the newly-formed Proto-Caribbean ocean crust.

(3) During the Middle Cretaceous, the island arc was being uplifted, probably involving parts of the continental slopes in the subduction zone. In the arc both volcanic and plutonic alkaline rocks occurred. The collision and acretion of the island arc to NAM started at least in the Late Cretaceous.

(4) Due to the convergent movement of the Farallon plate, the polarity of subduction inverted in the Paleocene, and the Tertiary island arc was formed, stretching from the Cayman ridge and the Sierra Maestra in eastern Cuba to Puerto Rico.

Some points remain problematic: (a) the prolongation of the Central Cuban Thrust Zone to the east and the other Greater Antillean islands; (b) the age of metamorphism and the tectonic style of the metamorphic complexes (and ultrabasic rocks involved) of Cuba; (c) the magmatic events during continental rifting and postcollisional time; (d) the origin and the age of the basement of the Yucatan basin.

Acknowledgements. The financial support of the investigation by a grant of the Deutsche Forschungsgemeinschaft (DFG Tr 392 and Sta 362/1-1) is gratefully acknowledged. We thank an anonymous reader for critical comments.

References

ANDERSON, T. H. & SCHMIDT, V. A. (1983): The evolution of the Middle America and the Gulf of Mexico-Caribbean Sea region during Mesozoic time. - Geol. Soc. Amer. Bull., 94 (8): 941-966; New York.

BUFFLER, R. T., SHAUB, F. J., HUERTA, R., IBRAHIM, A. B. K. & WATKINS, J. S. (1981): A model for early evolution of the Gulf of Mexico basin. - Oceanol. Acta (Proc. 26. IGC Paris 1980, Coll. C3), 1981: 129-136; Paris.

BURKART, B., DEATON, B. C., DENGO, C. & MORENO, G. (1987): Tectonic edges and offset Laramide structures along the Polochic fault of Guatemala and Chiapas, Mexico: Reafirmation of large Neogene displacement. - Tectonics, 6 (4): 411-422; Washington.

DONNELLY, T. W. (1989): Geologic history of the Caribbean and Central America. - In: BALLY, A. W. & PALMER, A. R. (eds.): The geology of North America, A: 299-321; Boulder, Colo.

DONNELLY, T. W. & ROGERS, J. J. W. (1980): Igneous rocks in island arcs: The northeastern Caribbean compared with the worldwide island-arc assemblages. - Bull. Volcan., 43 (2): 347-382; Napoli.

DUBLAN, L. & AVAREZ, H. et al. (1986): Informe final del levantamiento geológico y evaluación de minerales útiles en escala 1 : 50 000 del polígono CAME I, zona Centro. - CNJG, MINBAS, 1986; La Habana. [Unpubl.]

ENGEBRETSON, D. C., COX, A. & GORDON, R. G. (1985): Relative motion between oceanic and continental plates in the Pacific basin. - Geol. Soc. Amer. Spec. Pap., **206**: 59 pp.; New York.

FREEMAN-LYNDE, P. R. & RYAN, W. B. F. (1987): Subsidence history of the Bahama escarpment and the nature of the crust underlying the Bahamas. - Earth Planet. Sci. Lett., **84**: 457-470; Amsterdam.

GEYER, O. F. (1973): Das präkretazische Mesozoikum von Kolumbien. - Geol. Jb., **B 5**: 156 pp.; Hannover.

GROW, J. A. & SHERIDAN, R. E. (1981): Deep structure and evolution of the continental margin off the eastern United States. - Oceanol. Acta (Proc. 26. IGC Paris 1980, Coll. C3), **1981**: 11-19; Paris.

HACZEWSKI, G. (1976): Sedimentological reconnaissance of the San Cayetano formation: An accumulative continental margin in the Jurassic of western Cuba. - Acta Geol. Polonia, **26** (2): 332-353; Warszawa.

HATTEN, C. W., SOMIN, M., MILLAN, G., RENNE, P., KISTLER, R. W. & MATTINSON, J. M. (1988): Tectonostratigraphic units of Central Cuba. - Trans. 11th Caribbean Geol. Conf.: 35.1-35.13; Barbados.

ITURRALDE-VINENT, M. & MARI, T. (1988): Toleítas del Titoniano medio en la Sierra de Camaján, Camagüey. - Rev. Tecnol., **18** (1): 25-32; La Habana.

ITURRALDE-VINENT, M. & THIEKE, U. et al. (1987): Informe final sobre los resultados del levantamiento geológico complejo y búsqueda acompañante a escala 1 : 50 000 en el polígono CAME III, 1981-87. - CNFG, MINBAS, 1987; La Habana. [Unpubl.]

JÄGER, W. (1972): Zur Lithologie, Tektonik und Vererzung im Gebiet von Matahambre (Provinz Pinar del Rio, Kuba). - Jb. Geol., **4**: 347-385; Berlin.

JOLLY, W. T. (1971): Potassium-rich igneous rocks from Puerto Rico. - Geol. Soc. Amer. Bull., **82**: 399-408; New York.

KANCHEV, I. et al. (1978): Informe geológico de la provincia Las Villas - Resultados de las investigaciones y levantamientos geológicos a escala 1 : 250 000 durante el período 1969-75. - Acad. Cienc.; La Habana. [Unpubl.]

MILLAN, G. & MYCZYNSKI, R. (1978): Fauna Jurasica y consideraciones sobre la edad de las secuencias metamórficas del Escambray. - Inf. Cient. Tecn., Acad. Cienc. Cuba, **80**: 14 pp.; La Habana.

MOSSAKOWSKI, A. A. & ALBEAR, J. F. (1978): Estructura de cabalgamiento de Cuba Occidental y norte e historia de su formación a la luz del estudio de los olistostromas y molasas. - Cienc. Tierra y Espacio, **1**: 3-31; xxxx.

PERFIT, M. R. & HEEZEN, B. C. (1978): The geology and evolution of the Cayman Trench. - Geol. Soc. Amer. Bull., **89** (8): 1155-1174; New York.

PINDELL, J. L. & DEWEY, J. F. (1982): Permo-Triassic reconstruction of western Pangea and evolution of the Gulf of Mexico/Caribbean region. - Tectonics, **1** (2): 179-211; Washington.

PIOTROWSKA, K. (1993): Interrelationship of the terranes in western and central Cuba. - Tectonophysics, **220**: 273-282; Amsterdam.

PSZCZOLKOWSKI, A. (1986): Secuencia estratigráfica de Placetas en el área limítrofe de las provincias de Matanzas y Villa Clara (Cuba). - Bull. Pol. Acad. Sci., Earth Sci., **34**: 67-79; Warszawa.

PSZCZOLKOWSKI, A. et al. (1975): Texto explicativo del mapa geológico a escala 1 : 250 000 de la provincia de Pinar del Rio. - Acad. Cienc.; La Habana. [Unpubl.]

RJABUCHIN, A. G., CECHOVIC, V. D., ZONENSHAIN, L. P. & CHAIN, V. E. (1983): Evoluzija meksikano-karibskovo regiona. - Geotektonika, 6: 73-92; Moskva. [Russ.]

RODRIGUEZ, P. (1987): División estratigráfica de la formación Esperanza y comparición de los cortes de las subzonas Esperanza y Sierra del Rosario. - Mem. III. Encuentro cient.-tecn. geol., 1987: 46-50; Pinar del Rio, Cuba.

ROSENCRANTZ, E. (1990): Structure and tectonics of the Yucatan basin, Caribbean Sea as determined from seismic reflection studies. - Tectonics, 9 (5): 1037-1059; New York.

ROSENCRANTZ, E., ROSS, M. I. & SCLATER, J. G. (1988): The age and spreading history of the Cayman Trough as determined from depth, heat flow, and magnetic anomalies. - J. Geophys. Res., 93: 2141-2157; Richmond/Va.

ROSS, M. I. & SCOTESE, C. R. (1988): A hierarchical tectonic model of the Gulf of Mexico and Caribbean region. - Tectonophysics, 155 (1-4): 139-168; Amsterdam.

SEGURA SOTO, R., MILIAN, E. & FERNANDEZ, J. (1985): Complejos litológicos del extremo noroccidental de Cuba y sus implicaciones estratigráficas de acuerdo con los datos de las perforaciones profundas. - Rev. Tecnol., XV (1): 32-36; La Habana.

SOMIN, M. L., ARAKELJANZ, M. M. & KOLESNIKOV, E. M. (1992): Vozrast i tektoniceskoje znacenije vysokobariceskich metamorficeskich porod Kuby. - Izvest. AN Rossija, Ser. Geol., N3: 91-104; Moskva. [Russ.]

SOMIN, M. L. & MILLAN, G. (1981): Geologija metamorficheskich kompleksov Kuby. - Isdat. Nauka, 1981: 219 pp.; Moskva. [Russ.]

STANEK, K. P. & CABRERA, R. (1992): Tectono-magmatic development of Central Cuba. - Zbl. Geol. Paläont. Teil I, 1991 (6): 1571-1580; Stuttgart.

STEPHAN, J. F., MERCIER DE LEPINAY, B., CALAIS, E., TARDY, M., BECK, C., CARFANTAN, J. C., OLIVET, J. L., VILA, J. M., BOUYSSE, P., MAUFRET, A., BOURGOIS, J., THERY, J. M., TOURNON, J., BLANCHET, R. & DERCOURT, J. (1990): Paleogeodynamic maps of the Caribbean: 14 steps from Lias to Present. - Bull. Soc. géol. France, (8), VI (6): 915-919; Paris.

ZELEPUGUIN, V., LILAVATTI, D., FONSECA, E., GILLA, M., DOMINGUEZ, E. & TORRES, M. (1986): Petrología de las rocas vulcanógenas y vulcanógeno-sedimentarias de Cuba. - Inf. de investigac., Centro de Investigac. Geol.; La Habana. [Unpubl.]

Address of the authors:

Dr. KLAUS-PETER STANEK and S. VOIGT, Bergakademie Freiberg, Institut für Geologie, Bernhard-von-Cotta-Str. 2, D-09599 Freiberg/Sa.