Geologica Acta, Vol.4, Nº1-2, 2006, 1-5
Available online at www.geologica-acta.com

geologica acta

Foreword

Project 433
Caribbean Plate

Caribbean Tectonic, Magmatic, Metamorphic and Stratigraphic Events. Implications for Plate Tectonics

(UNESCO/IUGS IGCP Project 433 “Caribbean Plate Tectonics”)

M.A. ITURRALDE-VINENT[1] **and E.G. LIDIAK**[2]

[1] **Museo Nacional de Historia Natural**
Obispo no. 61, Plaza de Armas, La Habana 10100, Cuba. E-mail: iturralde@mnhnc.inf.cu

[2] **Department of Geology and Planetary Science, University of Pittsburgh**
Pittsburgh, Pa., U. S. A. E-mail: egl@pitt.edu

THE IGCP PROJECT 433

The present volume resulted from the UNESCO/IUGS Project 433 “Caribbean Plate Tectonics”, which during the years 2000-2005 organized scientific meetings and field workshops in several countries as Barbados, Brazil (Rio de Janeiro), Costa Rica, Cuba (central, western and eastern), Germany (Freiberg and Stuttgart), Guatemala, Italy (Florence), Spain (Granada and Barcelona), United Kingdom (Leicester) and United States of America (Boston and Austin). Participants in the project include geologists from Argentina, Barbados, Canada, Colombia, Costa Rica, Cuba, Dominican Republic, France, Germany, Guatemala, Hungary, Italy, Jamaica, Japan, Mexico, New Zealand, Nicaragua, Panama, Peru, Poland, Puerto Rico, Spain, Trinidad & Tobago, United Kingdom, USA, and Venezuela. A sequential development of the project is available at the website http://www.ig.utexas.edu/CaribPlate/CaribPlate.html which includes the project description, reports of the meetings, Caribbean bibliography, Caribbean models comparison, interesting information and a forum. The forum contains important papers and presentations about Caribbean Plate Tectonics (as ppt and pdf files). In the future this web site will serve as a permanent source of information about Caribbean Plate Tectonics.

The primary goal of the project was to pursue a consensus regarding the basic principles for further development of Plate Tectonics models on the origin and evolution of the Caribbean plate. Although this goal has not been fully achieved, major advancements have been made in clarifying and refining geologic models and in understanding critical details of regional and local geology, geochemistry, petrology, and tectonics that bear on the origin of the Caribbean plate.

A further major aim of this project was to improve communication within the Caribbean geoscience community and, in order to achieve this goal, the email group carib@yahoogroups.com was founded, which now serves as a highway for exchanging useful information concerning new publications, scientific events and news, and a question/answer forum which is widely used to search for information among Caribbean group members. The group has kept a low profile, in order to avoid loading the members with excessive emails. This group will also be kept active after the termination of the project.

Throughout the project we have encouraged debate on understanding the origin and evolution of the Caribbean, and Plate Tectonics models of the region. The Volume editors are more than pleased to present in this memoir a true example of the kind of debate that characterized the project.

Two groups of papers are presented in this volume of **Geologica Acta**. The first group includes new scientific research papers on the Stratigraphy, Paleontology, Structural Geology, Igneous and Metamorphic Petrology, and Geochronology of selected areas of the Caribbean realm. These papers present a significant amount of new data and new interpretations, whose practical and theoretical value transcend the limits of the Caribbean realm. The majority of these papers present arguments favoring the allochthonous origin of the Caribbean Plate. Within this framework, the authors raise multiple questions concerning the way the allochthonous model needs to be applied in particular areas. In the second group of papers *pro and con* arguments of an autochthonous versus allochthonous model of the Caribbean tectonic plate are discussed by Giunta and Beccaluva, Pindell et al., and James. The last author criticizes, in great detail, most of the basic tenet of the allochthonous model. Even if one does not agree with his in situ tectonic concept, we strongly recommend that this paper be read with care because it introduces many important questions.

CARIBBEAN PLATE TECTONICS: STATUS OF THE DEBATE IN THE YEAR 2005

This memoir, indeed, is a golden spike in the continuing scientific debate concerning the origin of the Caribbean that has gone on for more than 100 years. The questions and answers presented here, at the beginning of the XXI Century, will provide a useful forum to guide and encourage further research. In order to promote continuing discussion the Volume editors address additional comments about several problems and key issues concerning the interpretation of the Geology and Tectonics of the Caribbean realm, problems that have been the subject of debate as part of the project's activities.

From simplicity to complexity

A major trend in the scientific scenario of the Caribbean region is the fact that, as additional research and subsequent knowledge accumulate, the geological picture becomes more complex. New investigations are demonstrating that some concepts need to be modified, sometimes drastically. Good examples are the investigations of the ophiolitic rocks associated with foldbelts around the Caribbean (see Lewis et al.; Giunta and Beccaluva). This complexity is particularly evident in the Cuban fold belt where García-Casco et al., and Proenza et al. demonstrate that the so-called "Northern Cuban Ophiolite Belt" once recognized as being a continuous tectonic entity is in reality poly-genetic and needs to be subdivided into distinct units that take into account the petrology and age of the igneous rocks and the characteristics of the metamorphic inclusions in serpentinitic mélanges.

The so-called Primitive island arc tholeiites (IAT) of eastern Cuba (Proenza et al.) are another example of this complexity. These rocks are now recognized as being of Late Cretaceous age (Iturralde-Vinent et al.), whereas the previously accepted age for this kind of complex in the Caribbean was Early Cretaceous. Pindell et al. speculate that these and similar geochemical and petrological variations of a geologic unit along strike may be due to local processes and inhomogeneities of the crust, not necessarily reflecting different geotectonic scenarios. The contributions by Jolly and Lidiak, Jolly et al., Proenza et al., Gazel et al., and Denyer et al. are good examples of using discriminating geochemical methods to characterize different geotectonic scenarios. They corroborate that variations in the composition of the crust and mantle occur and can be identified geochemically. Furthermore, as noted by Jolly and co-workers, Gazel et al. and Denyer et al., geochemical and petrologic results need to be evaluated in light of stratigraphy, geologic structure, and tectonic setting in order to understand its ultimate significance. Nevertheless, these and similar results are clear indication that understanding the origin of the Caribbean requires the combination of different techniques and collaboration of various experts.

Particularly interesting are some sedimentologic, tectonic and magmatic disparities between the leading and trailing edges of the Caribbean plate. In the area of Central America (Panamá and Costa Rica), excellent examples of the Caribbean oceanic plateau (Nicoya Complex), the subduction-related accretionary wedge (Santa Elena peninsula), and the various events produced by the emplacement of a mantle plume occur (Denyer et al.; Gazel et al.; Denyer and Baumgartner; and Baumgartner and Denyer). However, although the Duarte Complex (Hispaniola) and the Bermeja Complex (Puerto Rico) in the Greater Antilles belt are generally correlatable with some elements of the Nicoya and Santa Elena sections, as they both yield Jurassic and Cretaceous radiolarites associated with oceanic magmatic rocks, they present differences in composition and structure. For example, the Duarte complex shows no evidence of being emplaced by a mantle plume as does the Nicoya; and Bermeja shows few similarities to Santa Elena. Along the leading edge of the Caribbean plate in the Greater Antilles (Cuba, Hispaniola, Jamaica) subduction-related serpentinitic melanges may occur with inclusions of HP/LT metamorphic rocks, which are probably correlatable with Guatemalan ophiolites cropping out associated with the Motagua-Polochic fracture zone. These serpentinitic melanges are associated with collisional margins, and they do not occur elsewere in Central America south of Guatemala. Furthermore, Cretaceous and early Paleogene volcanic arc sections are particularly well developed in the Greater Antilles where they are present as IAT and calc-alkaline (CA) assemblages. Similar magmatic suites are also probably present in Costa Rica and Panamá, but these rocks have not yet been studied in detail. CA assemblages of late Tertiary age are also widespread in the Lesser Antilles and Cental America, not in the Greater Antilles. These disparities suggest that the leading and trailing margins of the Caribbean Plate underwent different geologic histories.

In situ vs. allochthonous origin of the Caribbean Plate

A major goal of this project was finding key clues to resolve the allochthonous vs *in situ* controversy regarding the origin of the Caribbean Plate. The controversy continues, and advocates of both ideas present their arguments here (James; Pindell et al.).

As previously noted, most project participants have adopted the allochthonous model. According to this model, the Caribbean originated and evolved in three main stages. The first one, or *ProtoCaribbean stage*, took place from latest Triassic through the Early Cretaceous, concurrently with the breakup and disruption of Pangea and the evolution of an *in situ* oceanic crust in the Gulf of Mexico and the Caribbean realm. The second or *MesoCaribbean stage*, began in Early Cretaceous time, coincidendal with extensive development of volcanic island arcs in the east-central Pacific Ocean which defined the converging margins of the Caribbean Plate (in the trailing edge: present nuclear Central America; and in the leading edge: Greater Antilles—Aves Ridge—Caribbean Mountain System of Venezuela). As a corollary of these ideas, it follows that the Caribbean Plate originated within the Pacific Ocean. The third or *NeoCaribbean stage*, started when the Caribbean Plate began an active eastward drift with respect to the North and South American plates. In this process the ProtoCaribbean lithosphere was largely subducted and overridden by the allochthonous Caribbean Plate. The time of initialization of this third stage is a matter of debate, as some authors favor an early Cretaceous Aptian date, while others present arguments to support a latest Cretaceous (latest Campanian-Maastrichtian) date. Taking into account the uncertainties of this general model, considerable new work and reinterpretation of geologic data needs to be carried out before local events may be properly integrated into the regional tectonic models.

Great Arc vs. Multiple Arcs

This issue has been a matter of much discussion in the project reports, meetings and field trips (visit project's web site), and is reflected by several papers included in this volume (García-Casco et al.; Proenza et al.; Iturralde-Vinent et al.; Rojas-Agramonte et al., Jolly et al.; Jolly and Lidiak; Giunta and Beccaluva; Pindell et al.). The concept of a single Great Arc shaping the evolution of the Caribbean Plate, championed in this volume by J. Pindell and colleagues, is based on the general argument that the most important tectonic events in the Caribbean realm, associated with the evolution of the leading edge of the plate, are related to a subduction reversal (flip) that took place within the Aptian (circa 120 Ma). But the Late Cretaceous (Late Campanian and Maastrichtian)-Paleocene events are as important or even locally more important than the Aptian one, as demostrated in several papers in this volume (Mitchell; Iturralde-Vinent et al.; Rojas-Agramonte et al.; García-Casco et al.). Pindell et al. in their contribution, now propose that the Great Arc ended, or had an interruption, in the Paleocene and a new set of arcs evolved thereafter. This is precisely the kind of evolution the Multiple Arc concept is promoting.

The Multiple Arc concept, championed by Iturralde-Vinent and also supported by other researchers (Jolly et al., García-Casco et al.; Giunta and Beccaluva), proposes that not a single, but several arcs were active during Caribbean evolution beginning in the Cretaceous. It is primarily based on growing evidence pointing to the occurrence of several important pan-Caribbean tectonic events that took place in the Aptian, Santonian, late Campanian, Maastrichtian-Paleocene, Middle Eocene, Latest Eocene and Early to Middle Miocene. These events produced partial or total extinction of arcs or arc segments, formation of new arcs, deep seated metamorphism and exhumation, deformations and regional unconformities, modifications in arc geochemistry and geometry, as well as subduction flipping and/or changes in the angle of subduction (García-Casco et al.; Proenza et al.; Rojas-Agramonte et al.; Mitchell; Denyer et al.; Iturralde-Vinent et al.).

Tectonic terranes

Ever since the first meeting of the project we have been debating the concept and use of the term tectonic terrane. Terrane tectonics is an integral part of Caribbean geology as many tectonic crustal fragments have been transported along plate boundaries. In order to produce a sound model for the evolution of the region, terranes have to be dismembered into their original components and palinspasticaly reconstructed *vs* time. Important examples are Piñón-Dagua, Siquisiqui, Villa de Cura, Sierra Bermeja, Chorotega, Chortis, Maya, Guaniguanico, Escambray and Pinos terranes, just to mention a few. Some of the current Caribbean Plate Tectonic models do not take sufficiently into account the fact that the present composition, shape and size of a terrane is the result of a long period of formation, deformation and tectonic transport. Models depicting the size and shape of tectonic terranes unchanged during their *in situ* and later allochthonous evolution are inappropriate. For example, the Escambray Terrane of Cuba is a Mesozoic poly-genetic unit incorporating fragments of oceanic crust and continental passive margin sections, which were partially introduced and amalgamated into a subduction zone and are now exposed as a tectonic window (Stanek et al.; García Casco et al.). Therefore, its present size and shape has little to do with the paleogeographic scenario where their internal original elements were formed. Another problem concerning the use of terranes in the Caribbean, is their representation in maps and graphics without being formally defined. For example, a Cretaceous terrane named “Central Cuba” and identified as a distinctive geologic unit and with independent history can be totally misleading if it refers to the territory of present Central Cuba. Central Cuba was not a coherent geologic entity until the Middle Eocene. Therefore, we strongly recommend that the term terrane be avoided unless it is properly defined.

The concept of an island arc

This is a major point of debate in the interpretation of Caribbean Geology and Plate Tectonics. Pindell et al. raised the question concerning Dewey’s classification of arcs as compressional, neutral, or extensional depending on their tectonic style at any given time. Unfortunately, Caribbean arcs have not been subdivided into these three categories, a major task to be accomplished in the future. However, various component parts of complex arcs have been recognized, for example the trench, the forearc, the axial part of the arc, the intra arc basin, the back arc, the remnant arc, and the marginal sea or foreland basin. Identification of these elements is not an easy task, and debate on these matters usually takes place (Giunta and Beccaluva, James, Pindell et al., García-Casco et al.; Jolly et al., Iturralde-Vinent et al.). In each of the Greater Antillean islands, only parts of the complete arc complex are found. Fragmentation and dispersion of the elements of the arcs are the result of wrench (and transform) faults that occur along the strike of the arcs and along the plate boundaries, but also as a result of complex subduction-obduction events. These processes dismembered and deformed the architecture of the arcs, elongated the arc complexes along their strike, and reduced their width. To illustrate this idea, consider, for example, the fate of the Early Cretaceous arc now recognized in the Circum Caribbean Fold Belt. Implicit in the idea of a Pacific origin of the Caribbean Plate is that the Early Cretaceous arc developed at the leading edge of the plate should have been of no more than several hundred km in length (Pindell), while its fragments have been dispersed during the Late Cretaceous-Present eastward drift of the plate along several thousand km (the present size of the Circum Caribbean Belt). Consequently, it follows that the Late Cretaceous-Present volcanic-arc sections cropping out all along the Caribbean Belt should rest on top of the Early Cretaceous volcanic arc sections only locally (Los Pasos Fm, Pre-Camujiro Fm, Los Ranchos Fm, Guamira basalts, and many others). In consequence, the present geometry of the volcanic arc complexes in the Greater Antilles cannot be resolved without careful palinspastic reconstructions, locality by locality. Examples of this kind of exercise are present in various papers presented in this volume, but the Volume editors strongly emphasize that much more work has to be done before the original geometry of the arcs in all the necessary details can be understood. For example, Pindell et al. argue that the Cretaceous arc-related rocks, as they occur in Central Cuba, represent a fore arc region, while the axial part of this arc is present in the Sierra Maestra Mountains of Cuba. This interpretation would imply that, unusually, the fore arc (Central Cuba) is built up by Neocomian(?)-Campanian primitive IAT and CA plutonic, volcanic and vulcano-sedimentary island arc suites, while the axial part of the arc (Sierra Maestra) is represented only by a poorly exposed Late Cretaceous (Albian-Campanian) mainly vulcanoclastic section. In Central America (Costa Rica) the occurrence of an Albian-Cenomanian volcanic arc is postulated by the occurrence of volcanic-derived clastic material in the Loma Chumico Formation, but the geometry of this arc is under debate and will be difficult to define without additional data (Denyer et al.). In eastern Cuba, Paleocene-Middle Eocene volcanic arc rocks probably represent a back arc-axial arc couple (Rojas Agramonte et al.), but the equivalent fore arc-subduction complex has not been identified, and may be present in western Hispaniola (Pindell et al.). Furthermore, neither in Hispaniola nor in Puerto Rico-Virgin islands are the volcanic arc sections fully represented, so many question about the geometry of the arc suites are under debate (Jolly et al.; Jolly and Lidiak).

CONCLUDING REMARKS

The scientific results presented herein –despite the questions remaining to be faced by future research– represent an important and useful base to encourage local and regional geological investigations, not only in the Caribbean area, but also elsewhere, because some of the issues debated here have to do with the basic principles of plate tectonic interpretation. For example, the expression of a mantle plume event in outcrops; the complex geochemical evolution of magmatic arcs; the problems in recognizing different arc elements within a deformed belt; the petrological identification of different subduction melanges along the strike of ophiolite outcrops and the debate concerning their interpretation; and some of the problems related to the definition and use of tectonostratigraphic terranes. We strongly believe that there is no clear distinction between basic and applied science. Every new scientific contribution ultimately is a step toward the cultural and economical development of society, which has been the true essence of our project.

ACKNOWLEDGEMENTS

The editorial work and assistance of the Editor and the Managing Editors of Geologica Acta is gratefully acknowledged. The editors of this memoir wish to recognize and extend their gratefulness to the following colleagues for their contribution to the quality of this volume, in reviewing the original draft of the papers. These are Thomas Anderson, Hans Ave Lallemant, Claudio Bartolini, Daniel Bernoulli, Ramón Capdevila, Mark Feigenson, Antonio García-Casco, Grenville Draper, Barry Hanan, William Harbert, Trevor Jackson, Wayne Jolly, Suzanne Kay, Peter Mattson, Martin Meschede, William McCann, Homer Montgomery, Andrés Pérez Estaún, James Pindell, Joaquín Proenza, Doug Rankin, John J. W. Rogers, Hernan Santos, Jinny Sisson, Hans Schellekens, Gary Scott, Rafael Torres Roldán, Jean Tournon, and Manfred van Bergen.