PROJECT 364:  
*Geological Correlation of Ophiolites and Volcanic Arc Terranes in the Circum-Caribbean Realm*

OFIOLITAS Y ARCOS VOLCANICOS DE CUBA  
(CUBAN OPHIOLITES AND VOLCANIC ARCS)

Editor:  
*Manuel A. Iturralde-Vinent*  
Museo Nacional de Historia Natural  
Capitolio Nacional, CH 10200,  
Ciudad de La Habana, CUBA
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This book is the first contribution of the IGCP Project 364: Geological Correlation of Ophiolites and Volcanic Arc Terranes in the Caribbean Realm, and is the product of several decades dedicated to research on the geological constitution of Cuba and its neighboring regions. The book presents several scientific articles on the geology of Cuba's ophiolites and volcanic arcs. The articles are written by professionals who have extensive field experience in the country. The majority of the data presented here are new, or otherwise constitute revised and updated versions of previous contributions. Much material that is presently scattered throughout little known and hard-to-find publications are presented is synthesized in several of the articles presented here. Each topic presents the opinion of its author or authors, which in some cases may be contradictory to that of others presented in the book; readers will thus have access, not only to the data, but also to the different viewpoints concerning crucial problems of Cuban geology and tectonics.

The first chapter is dedicated to general topics of the geology and geophysics of Cuba. The opening paper is a review of the geology of Cuba, where it is shown that in Cuba there are two major geologic units: the Meso-Cenozoic foldbelt and the overlying Neotauchthon. The Meso-Cenozoic foldbelt includes both continental and oceanic components. The main continental component is the southern margin of the Bahamas, which includes platform and slope deposits as well as an overlying foreland basin. Other continental units consist of the Southwestern Cuban Terranes, which are composed of metamorphosed continental margin deposits. Oceanic components of the Cuban foldbelt are the Meso-Cenozoic ophiolites and the Cretaceous and Paleocene-Eocene volcanic arc terranes. These Neotauchthon unconformably overlie the foldbelt and consists of slightly deformed, latest Eocene to Recent age sedimentary rocks. All the contributions in this book follow the nomenclature introduced here.

A plate tectonic model of the origin and evolution of Cuba and the western Caribbean according is also presented in the first paper. It includes a series of evolutionary cross sections and paleotectonic maps along with a comprehensive discussion of the main ideas of the model. The model is based on three concepts: 1) Cretaceous and Paleocene-Eocene volcanic arc terranes had different orientations and geographic distribution, 2) their respective subduction zones, in both cases, were located to the south of the present location of the arcs and dipped generally to the north, and 3) the arcs were formed within the Caribbean realm. This model, recently published (Iturralde-Vinent 1994), therefore differs from several other popular tectonic models for the evolution of the Caribbean area - primarily because of these main concepts. For balance, however, an example of a more conventionally accepted model is presented by Joseph Andó and colleagues (Chapter 2).
The structure and origin of the Yucatan basin are synthetically described by Rosencrantz, along with a discussion of the relationships between Cuba and the basin. This work suggests the existence of a suture of an inactive subduction zone south of Cuba, and shows its possible landward extension. Equally, the seismic profiles illustrated here do not indicate the existence of a Cretaceous-Eocene backarc basin south of Cuba, which has been suggested by several other authors (Pindell and Barrett, 1990; Mann et al., 1993).

The next paper consists of a comprehensive database of all K-Ar dates determined for Cuban rocks, in addition to a general interpretation of these ages. Within the continental units of the foldbelt, several well-dated samples indicate the existence of a Neoproterozoic metamorphic basement in part of the Bahamas. Within the oceanic elements of the foldbelt, the older K-Ar dates are Lower Cretaceous, which are from blocks of high-P meta-ophiolites in the one of the northern ophiolite melange units. The bulk of the K-Ar ages are generally younger than the protoliths, however, and are related with later thermal events.

The last paper in this chapter is an interpretation of the constitution and structure of the Cuban foldbelt, using gravity and magnetic fields, along with other geophysical and geological data. The interpretation is presented as a geophysical model which aims to provide a better understanding of the deep structure of the Cuban foldbelt.

Chapter 2 is dedicated to the ophiolites of Cuba. The majority of the papers included contain information compiled from the literature, but mostly present new data gathered by the authors. The first paper is a general view of Cuban ophiolites, with a discussion on the origin, age, styles of deformation, tectonic position and age of tectonic emplacement. It attempts to show the existence of several types of ophiolite, not only in Cuba, but also in the circum-Caribbean region. The ophiolites are separated into two main age-compositional units: the Jurassic-Early Cretaceous melanocratic basement (peridotite, transitional and cumulative complexes) and the Latest Jurassic-Cretaceous oceanic complexes. According to the present day tectonic position in Cuba, the ophiolites are further subdivided into the northern belt, the amphibolitic ophiolites and the ophiolites embedded within continental terranes. The first group is interpreted as a former backarc-marginal sea basin, the second group the metamorphic substrate of the Cretaceous volcanic arc, and while the last group may have a variety origins.

The second paper of the chapter is a description of the Jurassic-Early Cretaceous continental margin theolithic magmatic rocks represented in Cuba (Guaniquianico, Escambray, and Asuncion areas) as well as in nearby continental regions. It is interesting to note that this magmatism is generally older than the magmatism of the Greater Antilles' volcanic arc. It is considered that the magmatism developed during the extension (and thinning) of the continental crust associated with the opening of the Caribbean Tethys. This raises the question as to whether Lower Jurassic to Lower Cretaceous continental margin magmatism is recorded elsewhere in the Caribbean, and if so is it indicative of extension throughout the area.

In this context, the recent finding of a Lower Jurassic "oceanic terrane" in the Bermeja Complex of southwestern Puerto Rico (Montgomery et al. 1994), is particularly interesting. According to these authors, these crustal fragments are older than the opening of the Caribbean, and this suggest that the Caribbean crust originated within the Pacific realm. According to the model presented by those authors, the "old" Pacific crust was driven into the (north dipping) latest Jurassic-earliest Cretaceous subduction zone of the Greater Antilllan arc. However, it is very important to point out that, within the Bermeja ophiolite complex, there are blocks of radiolarites whose ages range from the Lower Jurassic to Campanian (Schelleken, Santos and Jaecks, 1994). If this is correct, it may suggest that the Bermeja complex is an accretionary prism structure like the Nicoya complex of Costa Rica. The interpretation of the Bermeja complex, therefore, is not simple.
The following two papers, by G. Millan, describe the metamorphic rocks related to the ophiolites. Among them, varieties are distinguished that formed under high pressure conditions, and others that originated at high temperatures. The high-pressure varieties are usually associated with the northern ophiolites, and occur as blocks, or fields of blocks, within a deformed serpentinitic matrix. Millan believes (as do J. And6 and his colleagues in another paper) that these inclusions demonstrate that the northern ophiolites were subject to subduction. K-Ar ages indicate that such "subduction" was active during the Cretaceous (>126 My until 67 My, at least). High-pressure metamorphic rocks also occur in the ophiolites that are tectonically interbedded within the Escambray Terrane of south-central Cuba. These metamorphic rocks are probably related with the shallow underthrust emplacement of the sialic Escambray terrane within a subduction zone (Chapter 1), in which case the K-Ar dates record a Late Cretaceous age for the emplacement.

According to Millan, the high-temperature metamorphic rocks are a consequence of ocean-floor metamorphism and/or related with high heat flow within the Cretaceous volcanic arc. He describes the Mabujina amphibolite complex, where high-T meta-ophiolites, meta-volcanics and meta-plutonics of the Cretaceous volcanic arc are found. The Mabujina amphibolites are a well exposed excellent example of metamorphosed crust below an island arc terrane, and show similarities with the Duarte complex of Hispaniola, and the Bermeja complex of Puerto Rico.

It is important to comment on Millan's conclusion of the existence of a pre-Aptian, northward-dipping, because it differs with several popular models of the origin of the Greater Antilles volcanic arc (Ross and Scotese 1987, Pindell and Barrett 1990). "Subduction" as the general phenomena of superposition of two crustal slabs can occur with and without equivalent arc's volcanism. Subduction not related with volcanic arc activity can take place either when the slope of the descending slab is very abrupt, or if it has a very low angle of dip. The shallow, low dipping "subduction", is more an underthrusting, while the steep-dipping subduction is more a dip-slip fault. The combination of dip-slip and strike-slip faults along the same trend can probably produce high-pressure metamorphism along linear zones, as is found within the northern ophiolite melange in Cuba. A geodynamic situation and mechanism similar to the one just referred to has been proposed by Schell and Tarr (1978; their figure 3) for the northern limit of the Caribbean Plate along the Puerto Rico trench. This kind of geodynamic situation may have existed south of the Bahamas during the Mesozoic (Iturralde-Vinent 1994, and first paper in Chapter 1).

The last topic of this chapter is the petrologic investigations of the Holguin ophiolites by a group of authors headed by Joseph And6. They describe the mineralogic and geochemical composition of the different rocks of the ophiolites, and also discuss the magmatic and metamorphic processes that created the ophiolite. This is the first detailed contribution of this kind devoted to Cuban ophiolites. The authors argue that these ophiolites originated within a fore-arc basin, in supra-subduction environment. The editor disagrees with several aspects of this interpretation: (a) because the basis for discriminating supra-subduction origin of the ophiolites is limited to four, out of a total of nine points plotted on a Cr vs Y diagram, a statistically small sample size, (b) several authors doubt to the validity of this diagram. An additional point of contention is the interpretation of the synorogenic sediments within the Holguin area. Iturralde-Vinent (1994) considers these deposits to be:

1) Campanian-late Maastrichtian rocks that belongs to the allochthonous arc,
2) deposits of the foreland basin, represented by: a) Paleocene-Lower Eocene olistostromes that usually occur within fault planes between the allochthonous volcanic arc suites and the ophiolite melange, and b) Middle to Upper Eocene olistostromes found in thrust planes between the ophiolite melange and the Bahamian continental margin.

Chapter 3 is concerned with Cuba's Cretaceous and Paleocene-Eocene volcanic arc rocks. As related rocks are present throughout the Greater Antilles, the problems discussed are of
importance to the whole Caribbean area. The question of the duration and continuity of arc magmatism in the Caribbean is examined here in the light of much new data. It is demonstrated that the Paleocene-Eocene arc is not a continuation of the Cretaceous arc, as implied by many models of the Caribbean tectonic evolution. Examination of the geology of the northern Caribbean appears to indicate that, five different, well defined stages of Caribbean arc magmatism can be distinguished.

1. The first shows volcanism of primitive island arc (PIA) type and is (?!) pre-late Albian in age. These rock types can be recognized in Cuba, Hispaniola, Puerto Rico and the Virgin Islands (Lebron and Perfit 1993).

2. The second stage is composed of a calc-alkaline island arc suite, dated as late Albian to early Santonian-Campanian, which again occurs throughout the Greater Antilles.

3. The third stage is short-lived, from Santonian to late Campanian, and is characterized by alkaline, potassium-rich geochemistry. So far such chemistry has only been recognized in Cuba, but it may occur in other areas of the Greater Antilles.

4. The fourth stage is Paleocene to Middle Eocene (though some authors report it beginning at the end of the Maastrichtian). The magmatism has typical calc-alkaline geochemistry, and is recognized at eastern Cuba, Hispaniola, Puerto Rico, the Virgin Islands, Aves Rise, Cayman ridge and Nicaragua rise.

5. The fifth, Upper Eocene to Recent stage occurs in the Lesser Antilles region and Central America. Four of the five Caribbean island arc magmatic stages are present in Cuba, and are subject of evaluation in this chapter.

The first topic of Chapter 3 is a general description of the Cretaceous volcanic arc stages as they occur in Cuba. Age and duration of arc magmatism are discussed, as are the age of the plutonic intrusions and related metamorphism. Both the arc's tectonic position and emplacement are discussed. This is the first detailed characterization of the volcanic-sedimentary sequences since the original description by Iturralde-Vinent (1994). The deposits are interpreted as originating in backarc, axial arc, or forearc basins. The base for this subdivision is the lithological composition of the sequences, the amount and composition of the extrusive bodies, and the occurrence of plutonic rocks and hornfelses.

The second contribution in this chapter concerns the stratigraphy of the arc-related deposits. This is organized from west to east, according to geographic areas. A description of the volcanic rocks of the Santa Clara region is lacking, but generally these are very similar to those of the Ciego-Camaguey-Las Tunas region. The descriptions include formation names, lithological composition, fossils, age and stratigraphic position. It should be noted that there are differing opinions regarding stratigraphical nomenclature in Cuba, therefore, the names used in this book are those favored by the individual authors. A short note addresses the presence of Lower Cretaceous pre-late Albian arc magmatism in different regions of Cuba, a subject poorly considered in the Cuban literature, despite its great interest as possible evidence of a short-lived primitive arc.

Chapter 3 concludes with a general description and characterization of the Paleocene-Eocene volcanic arc in eastern Cuba. The reason for this review is that there is much confusion in published literature concerning this tectono-magmatic event. Deposits of the backarc basin, of the axial arc zone and of the forearc-subduction zone complexes are characterized. The age span of the arc's magmatism, its paleogeography, an geologic evolution of the arc is also discussed. This arc is well exposed and represents an excellent example of an axial area-backarc basin environment.

In order to simplify locating references, these are grouped at the end of the book as a single unit. Such a grouping allows the references to be viewed as an updated bibliography on the Geology of Cuba.
This book would not have been possible without the collaboration offered by many persons and institutions. First, I would like to acknowledge the contributing authors, many of whom prepared their contributions in their own time, and who good naturedly responded to the Editor's requests. I would also like to thank several institutions which provided the Editor with various kinds of support during the two and a half years of the preparation of this book. These are the RARE Center for Tropical Conservation through its "Caribbean Scientific Initiative", the Institute for Geophysics (UTIG) and the Institute for Latin American Studies of the University of Texas at Austin, the Geology Department of Florida International University in Miami, the Woods Hole Oceanographic Institution, and especially, the Museo Nacional de Historia Natural in Havana. Grenville Draper kindly edited the original draft of this preface and reviewed some of the contributions. Other reviewers were R.T. Buffler (UTIG), F. Howell (U. of Texas at Austin), G. Millán (IGP), M. Perez (IGP), E. Rosencrantz (UTIG), K. Sukar (IGP) and L. Villalvilla (IGP). Last, but not least, I appreciate the great and diverse assistance provided by my wife and daughter.

Manuel Iturralde-Vinent

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Joseph Andó y cols., Department of Geochemistry, Eotvos Lorand University, H-1083 Budapest, Hungary
Manuel A. Iturralde-Vinent, Museo Nacional de Historia Natural, Capitolio, CH 10200, La Habana, Cuba
Laszlo Körös, Hungarian Geological Institute, H-1442 Budapest, Pf. 106, XIV Stefania út 14, Hungary
Miklós Kozák, Institute of Mineralogy, L. Koszutth University, H-4010 Debrecen, P.O. Box 4, Hungary
Guillermo Millán Trujillo, Instituto de Geología y Paleontología, Unión Geólogo-Minera, Vía Blanca y Carretera Central, San Miguel del Padrón, Ciudad de La Habana, Cuba
Elenor Nagy, Hungarian Geological Institute, H-1442 Budapest, Pf. 106, XIV Stefania út 14, Hungary
Jesús Pajón, Instituto de Geofísica y Astronomía, Ministerio de Ciencia, Tecnología y Protección Ambiental, Capitolio CH 10200, Ciudad de La Habana, Cuba
Manuel Pardo Echarte, Instituto de Geología y Paleontología, Unión Geólogo-Minera, Vía Blanca y Carretera Central, San Miguel del Padrón, Ciudad de La Habana, Cuba
Carlos Pérez Falカón, Centro de Investigaciones y Desarrollo del Petróleo, Apartado 370, CH-10100, Ciudad de La Habana, Cuba
Eric Rosenblatt, Institute for Geophysics, University of Texas at Austin, 8701 N MoPac Expressway, Austin, Texas 78759-8345, USA