Caribbean Geology Into the Third Millennium

Transactions of the Fifteenth Caribbean Geological Conference

Edited by **Trevor A. Jackson**

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CHAPTER 3

Remains of Oceanic Lithosphere in Cuba: Types, Origins and Emplacement Age

Jorge L. Cobiella-Reguera

ABSTRACT. Based on composition and tectonic position, three different types of oceanic lithosphere relicts (OLR) are present in Cuba: (1) the northern ophiolitic belt, a complex mélange that extends more than 1000 km along the island, (2) the amphibolite basement of the Cretaceous volcanic terrane, and (3) tectonic slices in the high pressure metamorphic Escambray Massif of southcentral Cuba. Although dated samples are few, the OLR in Cuba are confined to the Late Mesozoic. These oceanic relicts possibly originated in two different tectonic environments: (a) a small oceanic basin of Upper Jurassic–Neocomian age, related to drift between North America and a southern continent, and (b) a suprasubduction marginal basin between the North American passive margin and an Aptian-Albian volcanic arc. Tectonic emplacement of the Cuban relict oceanic lithosphere was most likely related to several tectonic events and processes. Serpentinite slices and high pressure amphibolites in the Escambray Mesozoic metasedimentary massif originated from Aptian-Albian subduction of the southern part of the small oceanic basin and collision of the southern continental mass with a volcanic arc in the Albian. The basement amphibolites of the volcanic arc terrane were derived from the Upper Jurassic–Neocomian oceanic crust that was metamorphosed by the high pressures and hot solutions related to the development of a Middle Cretaceous (Aptian-Albian) volcanic arc crust. Ophiolites of the northern belt were probably derived from both the northern part of the small Jurassic-Neocomian oceanic basin and the Aptian-Albian marginal (backarc) basin. Several distinct episodes of tectonic emplacement of the ophiolites of the northern belt are recognized: late Campanian, late Maastrichtian, late Paleocene–middle Eocene, and middle or late Eocene – this last episode limited to easternmost Cuba. A plate tectonic model is developed to summarize the data and ideas discussed in this chapter.

INTRODUCTION

THE PRESERVED RELICTS of oceanic lithosphere/ ophiolites are keys to the understanding of the geological evolution of such regions. For several decades the petrology of the Cuban ophiolites was not studied; it began to be studied about 15 years ago when the chemical and petrological composition was researched in some detail (Fonseca et al. 1984; Iturralde-Vinent 1990, 1996b; Andó et al. 1996). Some of these results are discussed below. Ocean basin relicts are abundant and varied in Cuba. In this chapter, the author reviews the available geologic data and then offers some speculations on the emplacement, age, and origin of the oceanic lithosphere relicts (OLR) in Cuba. The review will be drawn from relatively abundant literature on the theme published in the last few decades in Cuba and abroad. General papers include those of Knipper and Cabrera (1974), Pardo (1975), Khudoley and Meyerhoff (1971), Lewis and Draper (1990), Iturralde-Vinent (1996a), Pindell (1985, 1994), and

Pindell and Barrett (1990). Background information also comes from publications of a more restricted scope, including the 1996 collection of papers written by geologists and geophysicists on the geology of Cuba entitled *Ofiolitas y Arcos Volcánicos de Cuba* (*Cuban Ophiolites and Volcanic Arcs*).

In general, two main structural levels can be distinguished in Cuba: the upper level or neoautochthon that is made up of slightly deformed Eocene–Quaternary sedimentary rocks, and the lower level or Cuban fold belt that consists of a deformed and metamorphosed sequence of older rocks (Fig. 3.1). The lower level can be divided into two parts, a Lower Tertiary fold belt, and a pre-Cenozoic basement. The latter includes three different terranes that were accreted to the North American continental margin during the Cretaceous (Cobiella-Reguera 1998b). The OLRs that are the focus of this paper belong to the pre-Cenozoic basement. According to their composition and tectonic position, the three types of OLR that can be distinguished in Cuba are: (1) the northern ophiolitic belt (NOB), (2) the amphibolitic basement of the Cretaceous volcanic arc terranes, and (3) tectonic slices in the Escambray Massif in central Cuba.

THE NORTHERN OPHIOLITE BELT (NOB)

Most (> 90%) of the OLR in Cuba are included in the northern ophiolitic belt (NOB) which extends circa 1000 km along the northern half of Cuba from Cajálbana in the west to Baracoa in the east (Figs. 3.1 and 3.2). It represents an allochthonous belt that was transported from the south over the North American paleomargin and Lower Tertiary foreland basin of northern Cuba and in turn overidden from the south by the Cretaceous arc terrane. The NOB is a large mélange comprising ophiolitic lithologies, some of which have been metamorphosed (Millán-Trujillo 1996a) and also mixed with volcanic Cretaceous terrane. In western and central Cuba,

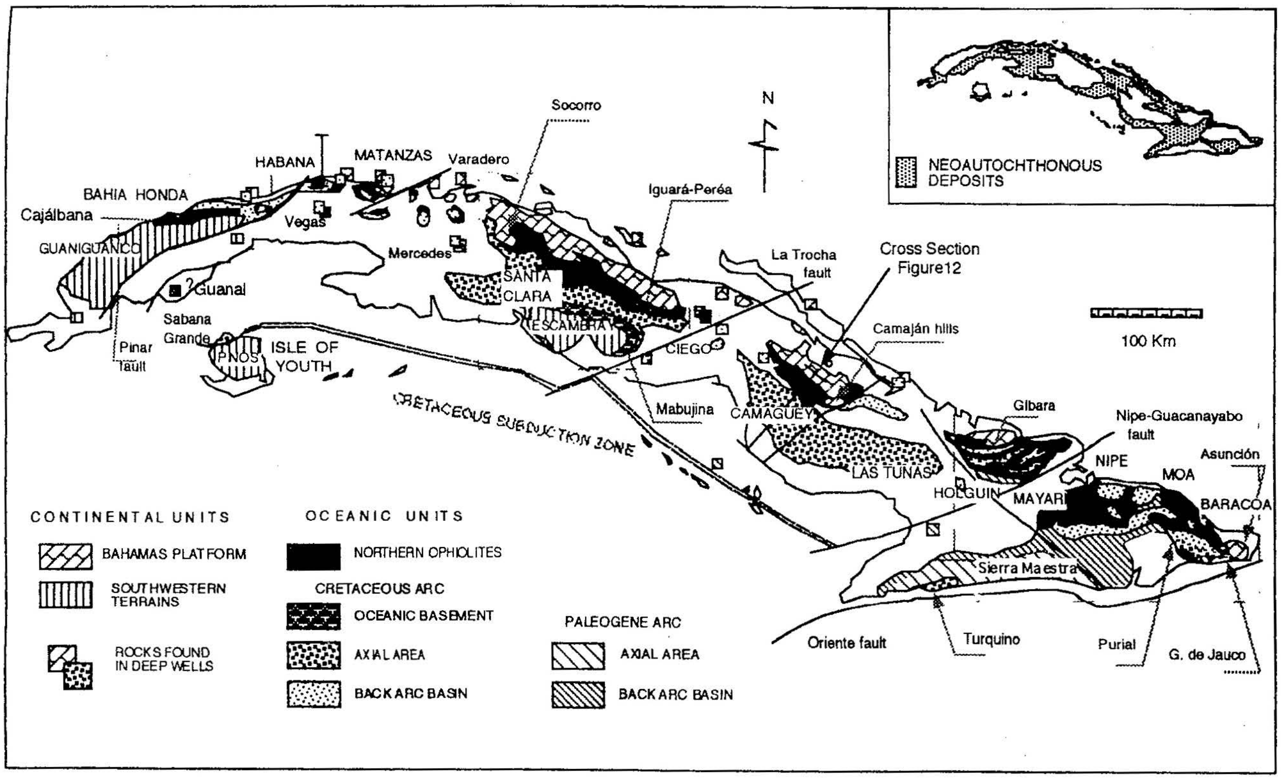

Figure 3.1 Map of Cuba showing major geologic features. Inset is a map showing the late-Eocene-Quaternary neoautochthonous deposits (from Iturralde-Vinent 1996a).

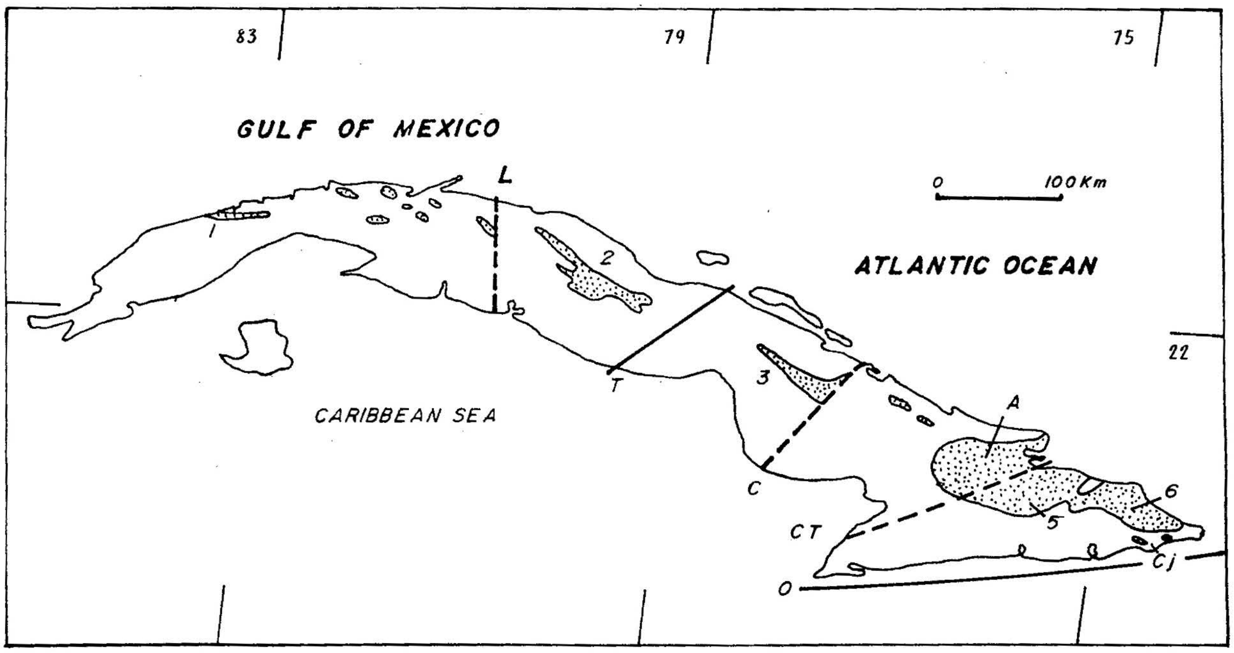

Figure 3.2 Map of Cuba showing the main massifs of the NOB (below the Cenozoic cover), and faults and lineaments related to deformation during the Cuban orogeny and ophiolite emplacement. The Figure also shows the small body of serpentinites at Cajobabo (cj).
L = Llabre lineament; T = La Trocha Fault; C = Camaguey lineament; Ct = Cauto lineament. 1 = Cajálbana and Bahía Honda ophiolites; 2 = Villaclara Massif; 3 = Camaguey Massif. Eastern Cuba ophiolites: 4 = Holguin Massif; 5 = Sierra de Nipe-Cristal Massif. 6. Moa-Baracoa Massif.

rocks of NOB tectonically overlie the Mesozoic beds of the North American passive margin and the lower Tertiary foreland basin (Figs. 3.2 and 3.3). However, in easternmost Cuba the NOB overlies the Maastrichtian sedimentary cover of the volcanic terranes. This area also contains thick olistostromes, rich in clasts of serpentinites, diabase, and other members of the ophiolitic suite (UKO1, Fig. 3.3). The Holguin Massif (Fig. 3.2), which occupies an intermediate position between western and eastern ophiolites of the NOB, contains an ophiolitic suite in which the degree of tectonic mixing is extreme.

Despite the tectonic complications and intense mixing, all parts of a standard ophiolite can be distinguished in the mélange of the NOB. Tectonized peridotites (serpentinites) and rocks of the stratified complex are the most common lithologies present (Knipper and Cabrera 1974; Iturralde-Vinent 1990, 1996b; Cobiella-Reguera 1984; Kozary 1968). The geochemistry of these ophiolitic rocks reveals two different origins, mid-oceanic ridge and suprasubduction (Andó et al. 1996; Rodriguez et al. 1987).

There are still too few dates for the rocks of the NOB, but fossils collected give Tithonian, Hauterivian-Barremian, and Aptian-Albian ages (Llanes-Castro, García-Delgado and Meyerhoff 1998; Andó et al. 1996; Iturralde-Vinent 1990). Although Cenomanian fossils have been reported, they are associated with rocks that are atypical of the ophiolitic suite (Iturralde-Vinent 1996b), or found in zones of tectonic mixing (Andó et al. 1996). Radiometric K-Ar ages vary from 160±24 to 52±6 Ma. The 160±24 Ma age was obtained from an anorthosite in the Camaguey Massif (Somin and Millán-Trujillo 1981; Iturralde-Vinent et al. 1996). This 160 date is interesting, as it coincides with the Callovian?-Oxfordian continental margin tholeiitic magmatism event in western and central Cuba (Cobiella-Reguera 1996).

The timing of tectonic emplacement varies along the strike of the NOB (Table 3.1 and Fig. 3.3) in which the age of final emplacement appears to

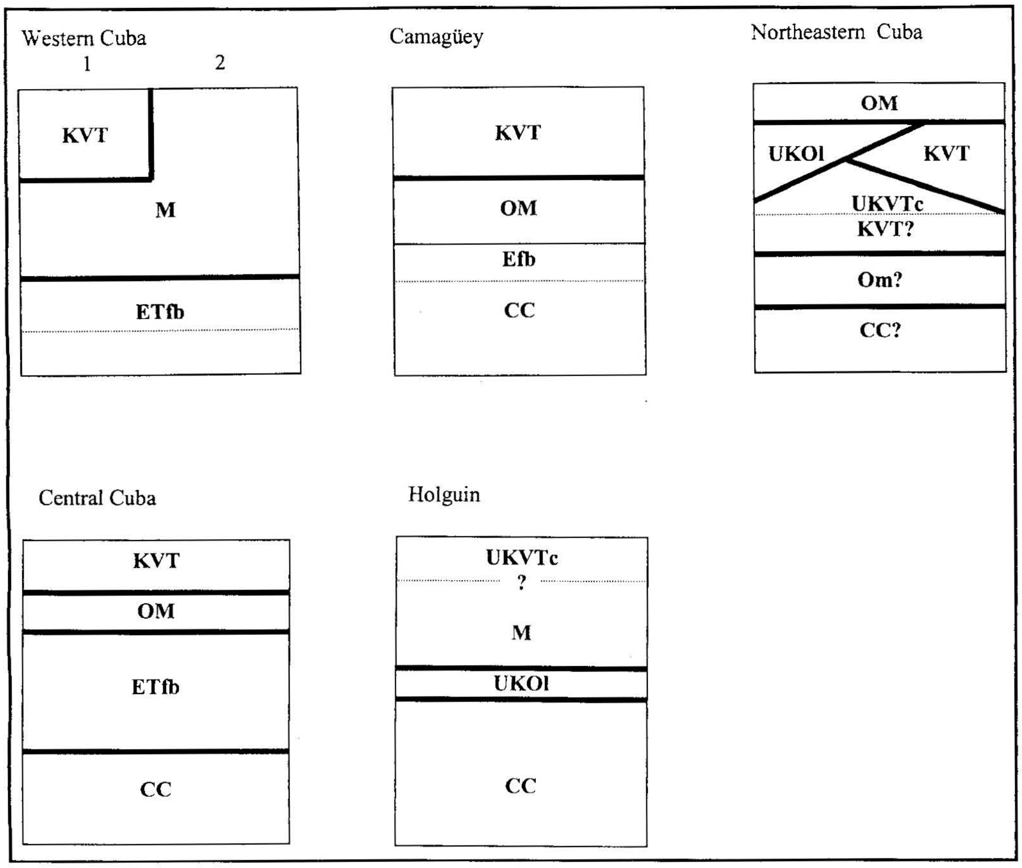

Figure 3.3 Diagram illustrating the emplacement relationship across the northern ophiolitic belt (NOB). KVT: Cretaceous volcanic arc terrane. M: Mélange (ophiolites + Cretaceous volcanic arc terrane). OM: Ophiolitic mélange. Etfb: Foreland basin (Upper Paleocene to lower Eocene olistostromes and turbidites in western Cuba, Upper Paleocene to middle Eocene in central Cuba). CC: Pre-Cenozoic North American continental crust. Efb: Upper Eocene foreland basin (olistostromes). UKO1: Maastrichtian ophiolitic olistostromes. UKVTc: Maastrichtian sedimentary cover of the volcanic terrane. Thick lines = overthrust planes; discontinuous lines = unconformities. In Western Cuba panel: (1) west of Havana city, and (2) east of Havana city.

young to the east (Cobiella-Reguera 1997, 1998a). To the west of the Camaguey Lineament (Fig. 3.2), the final emplacement of the ophiolites occurred during the late Paleocene–middle Eocene (locally Late Eocene) Cuban orogeny and is represented by a series of strike-slip fault blocks. In the author's opinion, evidence of the effects of the Early Tertiary Cuban orogeny in the Holguin Massif is not clear (Cobiella-Reguera 1984), although some geologists consider that these movements were as strong at Holguin as in western and central Cuba (Kozary 1968; Knipper and Cabrera 1974; Andó et al 1996; Iturralde-Vinent 1996a). In the huge massifs of easternmost Cuba, east of the Cauto Lineament, evidence of the Cuban orogeny is virtually absent. Instead the final emplacement here appears to be in the middle or late Eocene where a small serpentinite body near Sierra del Purial structurally overlies the middle to upper Eocene San Luis Formation (Fig. 3.3).

Based on the ages of the thick olistostromes (La Picota and Yaguajay formations), rich in ophiolitic clasts, the easternmost Cuban ophiolites, including the Holguin Massif, were initially unroofed in Maastrichtian time (Fig. 3.3). Thrust displacement of several dozen kilometres in this region was perhaps related to obduction (Cobiella-Reguera 1978; Cobiella-Reguera et al. 1984a). However, the first appearance of ophiolite clasts in Cuba occurs in the Upper Campanian conglomerates of western Cuba (Albear-Franquiz and Iturralde-Vinent 1985), which would suggest that this was the earliest date of emplacement.

THE AMPHIBOLITIC BASEMENT OF THE VOLCANIC TERRANES

The amphibolitic complex below the Cretaceous volcanics is the second type of OLR in Cuba. Although it is seen in eastern Cuba in the Gura de Jauco Formation (Millán-Trujillo 1996a), it is best exposed in central Cuba within the Mabujina complex (Somin and Millán-Trujillo 1981) as a sequence of melanocratic and minor ultramafic rocks, metamorphosed to high temperature/low pressure amphibolites. The original rocks were mainly gabbros (cumulative), with lesser amounts of diabases and silicic volcanics (Haydoutov, Boyanov and Millán-Trujillo 1989), and the chemistry of the metabasites is comparable to mid-ocean-ridge basalt (MORB). The Mabujina complex also contains arc volcanics and intrusives that have been transformed into gneisses (Somin and Millán-Trujillo 1981; Millán-Trujillo 1996b). In some places within the complex, weakly metamorphosed rock bodies, perhaps caused by volcanic arc magmatism, are also present (Millán-Trujillo 1996b). The Guira de Jauco Formation, in easternmost Cuba probably belongs to the basement of the volcanic terranes. The complex also records granitoid intrusions that possibly began in Albian time and may have lasted until the Campanian.

TECTONIC SLICES IN THE ESCAMBRAY MOUNTAINS OF CENTRAL CUBA

The Escambray Massif of central Cuba (Fig. 3.1) is part of the southern metamorphic terrane and is composed of metamorphosed and deformed Jurassic and Cretaceous passive margin sequences, characterized by low to moderate temperature and high pressure metamorphism (Somin and Millán-Trujillo 1981). These rocks are overthrusted by the Mabujina Complex and the Cretaceous volcanic arc terrane. Two types of OLR, occurring as thin tectonic slices, can be distinguished in the Escambray Mountains; these are high pressure/low temperature amphibolites with a tholeitic basalt protolith (Yayabo Formation), and a serpentinite mélange containing eclogites and other metabasic rocks. Both types are juxtaposed to the Mesozoic metasediments along thrust planes. U-Th radiometric ages (106 to 102 Ma) from the metamorphic zircons within the eclogites are Albian (Millán-Trujillo 1996a).

DISCUSSION AND SUMMARY

The history of the different OLR in Cuba is varied and complex. The NOB has been transported from the south over the North American paleomargin and the Lower Tertiary foreland basin of northern Cuba. These ophiolites are, in turn, overidden from the south by the Cretaceous volcanic arc terrane. Therefore the original position of the tectonic units was in the south prior to tectonic emplacement (Iturralde-Vinent 1996a). The Escambray Complex represents a huge tectonic window (Fig. 3.1) in which there are outcrops of highly deformed and metamorphosed rocks of a Mesozoic passive paleomargin, with thin slices of metamorphosed oceanic lithosphere that are below the Mabujina Complex and the Cretaceous volcanic terrane (Millán-Trujillo 1990, 1996b). In this latter case, the movement of the volcanic terranes seems to be from north to south (Millán-Trujillo 1990); the passive margin paleomargin, represented by the Escambray rocks, was originally situated to the south of the volcanic arc.

The mafic protolith of the Mabujina Complex is interpreted by Haydoutov et al (1989) and Millán-Trujillo (1996b) as the basement for the Aptian-Campanian volcanic arcs in central Cuba. Therefore, the metaophiolites of the Mabujina complex must be pre-Aptian in age. Similar amphibolites in eastern Cuba (Guira de Jauco Formation) are at least pre-Maastrichtian in age (Cobiella-Reguera et al. 1984). The MORB geochemistry of most of the metamafites of the Mabujina Complex suggests an oceanic ridge origin, but some calcalkaline rocks are also present in the complex (Millán-Trujillo 1996a). These calcalka-

line rocks include metatuffs, metaagglomerates, and metaandesite lavas. Greenschist facies mafic and felsic volcanic rocks occupy the highest structural levels of the complex. Low grade metamorphic lamprophyre and andesite dykes cross cut the amphibolites. Further, the Cretaceous volcanic arc rocks near the Mabujina Complex show evidence of dynamic metamorphism (Millán-Trujillo 1996b). Collectively, these data indicate that a volcanic arc was built on an oceanic crust, which was later modified by tectonism. The OLR in the Mabujina Complex seems to be derived from a Late Jurassic–Neocomian oceanic ridge created in a basin to the south of the Mesozoic passive margin of North America during the break up of Pangaea (Cobiella-Reguera 1998c). The high temperatures and hydrothermal solutions that were associated with the development of the Middle Cretaceous magmatic arc were responsible for the metamorphism of the OLR (Haydoutov et al. 1989). The amphibolites of the Guira de Jauco Formation of eastern Cuba were probably formed in a similar manner.

The major and trace element chemistry of the NOB of easternmost Cuba suggest a suprasubduction origin for at least a part of the massif. The petrochemical data suggest that the NOB probably originated in more than one distinct tectonic setting. In the Holguin Massif, geochemical data indicate two origins for the ophiolites – one, an oceanic ridge, and the other a suprasubduction back arc basin (Ando et al 1996). Heterogenities in the chemistry of the NOB ophiolites indicate different magmatic origins. Rodriguez et al (1987) concluded that these Cuban ophiolites contain both MORB and SSZ geochemical signatures.

The oldest ages obtained for the OLR in the NOB are Jurassic (Sonin and Millán-Trujillo 1981; Llanes-Castro, García-Delgado and Meyerhoff 1998). According to Pindell (1985, 1994), Iturralde-Vinent (1996a), and other sources, this represents the period of Pangaea break-up in Meso America, when the North American plate began its isolation from the other continents. Oxfordian (middle? and late) fissure magmatism recorded at the passive paleo margin of western Cuba (Cobiella-Reguera 1996) suggests that drifting continued after this break up. Therefore it seems likely that the first oceanic lithosphere, formed south of the North American Plate in present-day Cuba, was created between late Oxfordian and late Tithonian. The youngest ophiolites in the NOB are coeval with the oldest volcanic arc rocks (Aptian-Albian). As previously mentioned, this age overlaps with the age of the first volcanic arc rocks, which were formed on an oceanic basement (Haydoutov et al. 1989; Cobiella-Reguerra 1998c). Geochemical data for the NOB suggest that part of the NOB contains suprasubduction signatures (Proenza-Fernandez 1997) while other parts have N-type MORB signatures (Andó et al. 1996; Iturralde-Vinent 1996). Since there is no convincing evidence of Upper Cretaceous ophiolites in Cuba (Cobiella-Reguera 1998c), the process generating oceanic crust must have ended in the Albian. A reconstruction of the geological history during Late Jurassic–Early Cretaceous is shown in Figures 3.4 and 3.5.

The first evidence of the unroofing of the NOB rocks is seen in conglomerates of upper Campanian age in western Cuba (viz. Via Blanca Formation, Albear-Franquiz and Iturralde-Vinent 1985). In eastern Cuba, clasts derived from ophiolites are the main components in the Maastrichtian olistostromes (viz. La Picota and Yaguajay Formations, Jakus 1983) and are related to the northward thrusting of several tens of kilometres of the ophiolite massifs of the region (Fig 3.3 and Table 3.1). Unfortunately there has been no study of the sandstone composition of the uppermost Cretaceous in central Cuba, and therefore it is not known if the NOB was exposed in this region during that time.

Indirect evidence of the closure of the oceanic depression between the second volcanic arc in the Late Cretaceous and the North American Mesozoic paleomargin (Fig. 3.6) is present in the Campanian sediments of western Cuba, where the Moreno Formation of the paleomargin contains clastic sediments that are derived from the Cretaceous volcanic

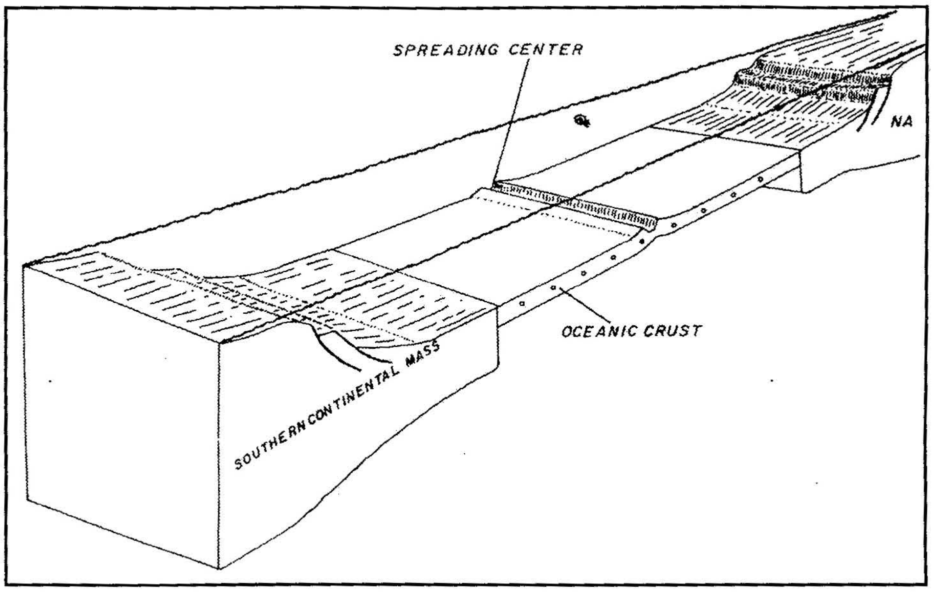

Figure 3.4 Late Jurassic–Neocomian paleotectonic and paleogeographic schematic model. As a consequence of Pangaea fragmentation, an oceanic basin was formed to the south of the North American Plate, owing to the separation and drifting of a southern continenetal mass.

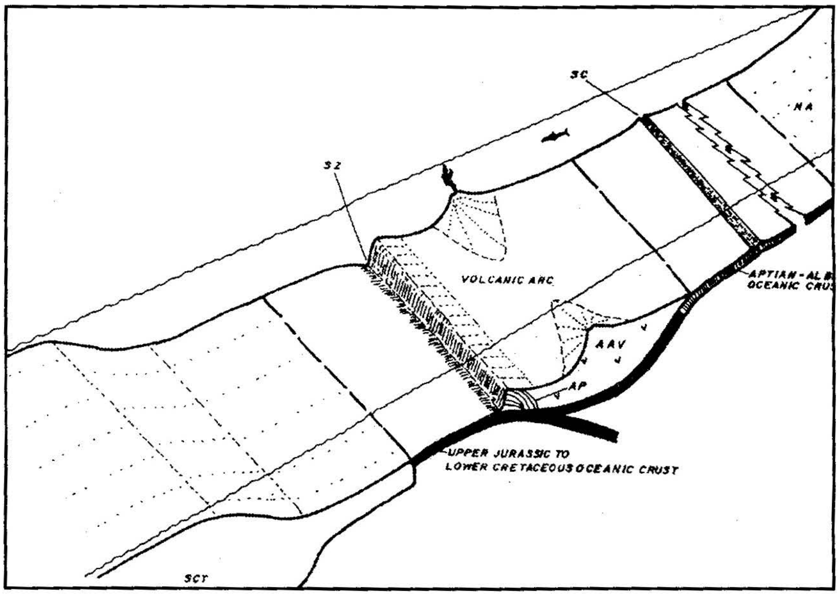

Figure 3.5 Aptian–Albian paleotectonic and paleogeographic schematic model (modified from Cobiella-Reguera 1998c) showing subduction of a Jurassic–Neocomian oceanic crust northwards beneath the Aptian–Albian volcanic arc and the accretion of SSZ lithosphere in the marginal basin at the back of the arc. SC = Spreading center; AAV = Aptian–Albian volcanic arc; AP = accretionary prism; SZ = subduction zone; NA = North American passive margin; SCT = Southern continental terrane.

terrane (Pszczolkowski 1994). This is only possible if the depression between the Late Cretaceous volcanic arc and the continental margin was not present in the late Campanian. Finally, a megaturbidite of late Maastrichtian or K/T boundary age (Pszczolkowski 1986, Cobiella-Reguera 1998b) is present in the continental paleomargin (Cacarajicara, Amaro and Camajan Formations) and in the volcanic arc sedimentary cover (Penalver Formation) but is not seen resting on the ophiolites. This suggests that at the Cretaceous demise, the NOB was obducted and the volcanic arc terrane and the North American paleomargin were juxtaposed to it. The unconformity that separates the volcanic terranes from the upper Campanian–Maastrichtian boundary could represent this event.

The last major event that affected the NOB was the Early Tertiary Cuban orogeny. Tectogenesis occurred in stages, in blocks bounded by strike-slip faults and lineaments (Cobiella-Reguera 1997). West of the Llabre Lineament, in western Cuba, the thrusting of the ophiolites on the Early Tertiary foredeep and the Mesozoic paleomargin of North America ceased in the early Eocene. However, the same process in central Cuba between the Llabre Lineament and the La Trocha Fault (Villaclara ophi-

TABLE 3.1 Timing of tectonic emplacement of ophiolites in the northern ophiolite belt (NOB)

EMPLACEMENT AGE	RELATED TO	REGIONS	RELATED SEDIMENTS
Late Middle to Late Eocene	Thrusting or gravity slide	Cajobabo (Sierra del Purial)	Turbidites
Middle to Late Eocene	Thrusting	Camagüey massif	Olistostromes
Late Paleocene to Middle Eocene	Thrusting	Villaclara ophiolites	Olistostromes and turbidites
Late Paleocene to Early Eocene	Thrusting	Ophiolites to the west of Llabre lineament	Olistostromes and turbidites
Late Maastrichtian	Thrusting (and obduction?)	Eastern Cuba massifs	Olistostromes and turbidites
Late Campanian-Maastrichtian	Obduction?	Havana ophiolites (and others?)	Turbidites and Olistostromes

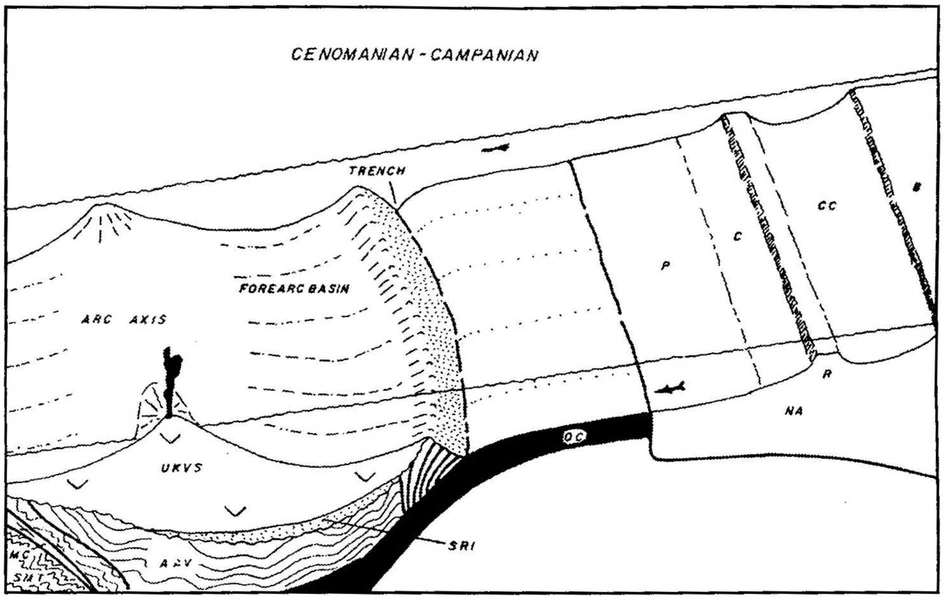

Figure 3.6. Cenomanian-Campanian paleotectonic and paleogeographic schematic model (modified from Cobiella-Reguera 1998c) showing subduction of former SSZ oceanic lithosphere southwards below a Late Cretaceous volcanic arc. The change in subduction was a consequence of the collision of the southern continental mass with the Aptian–Albian volcanic arc during the Albian. UKVS = Upper Cretaceous volcanics and sediments; SRI = Sediment rich interval; AAV = Aptian–Albian volcanic rock;. MC = Mabujina Complex; SMT = Southern metamorphic terrane; OC = Oceanic crust; NA = North American Plate;. P = Placetas zone (deep waters); C = Camajuani zone (talus); R = Remedios zone (carbonate bank); CC = Cayo Coco zone (deep channel); B = Bahamas platform.

olites) ended in the middle Eocene, and in eastern central Cuba it ended in late–middle Eocene or late Eocene, with the emplacement of the Camaguey Massif (Table 3.1). along the La Trocha Fault and Camaguey Lineament. East of the Camaguey Lineament there is no evidence of ophiolite emplacement related to the Cuban orogeny, except perhaps in the Holguin Massif.

The last emplacement event affecting the NOB is recorded in a small area near the mouth of the Cajobabo River in Sierra del Purial, in easternmost Cuba, where a serpentinite body rests on

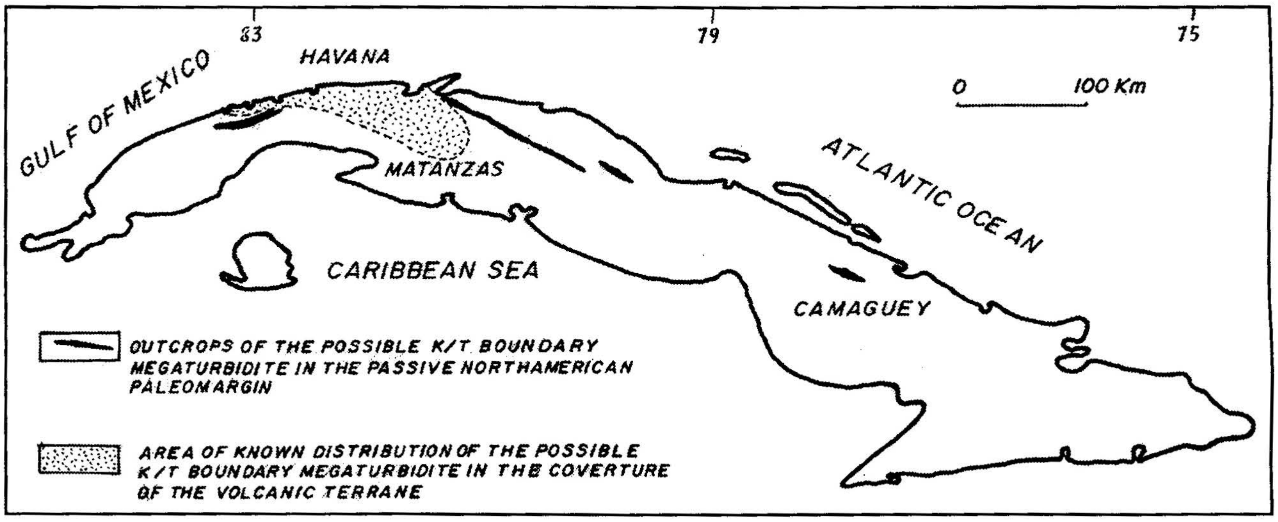

Figure 3.7 Map of the geographic distributionof the K/T boundary or uppermost Maastrichtian megaturbidite in Cuba (Cobiella-Reguera 1998c). The original distribution of the magaturbidite was modified by Early Tertiary thrusting (Cuban orogeny), especially in Western Cuba.

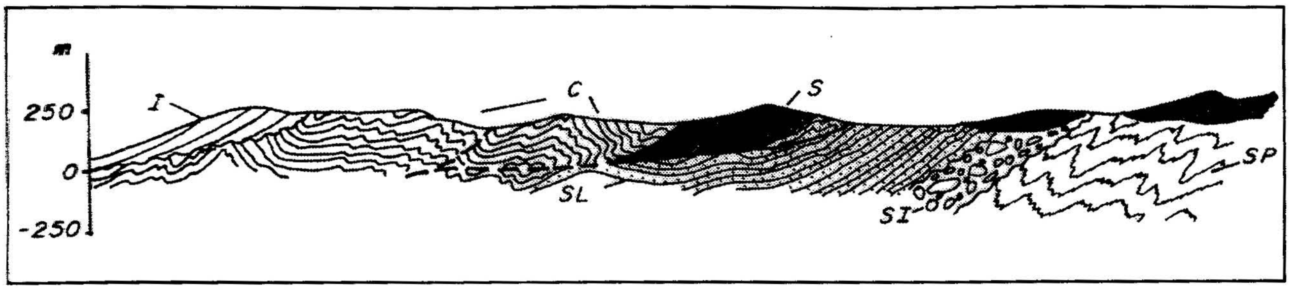

Figure 3.8 Cross section near Cajobabo River, southern Sierra del Purial, Guantanamo province (see location c in Fig. 3.2). Horizontal scale = vertical scale. SP = Sierra del Purial Formation (cretaceous arc metavolcanics and marbles); C = El Cobre Formation (lower Eocene arc volcanics with some sediments); SI = San Ignacio Formation (middle Eocene talus megabreccia); SL = San Luis Formation (middle and upper Eocene submarine fan? turbidites); I = Imias Formation (Upper Miocene–Pliocene talus deposits; S = serpentinite mélange; wavy lines = unconformities; thick lines = faults.

middle–upper Eocene deposits of the San Luis Formation (Fig. 3.3 and 3.8, Table 3.1). The thrusting seems to be related to the first strike-slip movements along the Oriente Fault that is a part of the present day boundary between the Caribbean and North American Plates.

Some of the slices of the OLR that are present in the high pressure metamorphics of the Escambray Massif contain metamorphic zircons with U-Th dates of 106–102 Ma. This suggests that thin slices of oceanic crust may have been emplaced into the southern passive margin during a subduction event in Albian time (Millán-Trujillo 1996a). This southern continental mass has been envisioned by some geologists (Iturralde-Vinent 1996a; Cobeilla-Reguera 1998b, c). Yayabo amphibolites are huge tectonic slices in northeastern Escambray, associated with serpentinites. The protolith was a tholeiitic basalt with interbedded silicites (Millán-Trujillo 1996a). In the author's opinion, these rocks were a part of the Upper Jurassic–Neocomian oceanic crust that was obducted and overthrusted during the Albian collision (Fig. 3.5) and which Iturralde-Vinent (1996a) classified as Cordilleran ophiolites. Iturralde-Vinent (1996b) also considered the serpentinites outcropping in the Guaniguanico mountains of western Cuba, which occur as small bodies along the thrust planes, to be Cordillera-type ophiolites.

The author has visited and studied in detail many outcrops of serpentinites and older rocks of the ophiolite suite in eastern Guaniguanico (Sierra del Rosario) and has interpreted them as olistoliths in tectonized olistostromes (Manacas Formation, Cobiella-Reguera 1998d). These olistoliths were derived from the erosion of the NOB during the Cuban orogeny, at the beginning of the early Eocene, based on similarities in composition and radiometeric ages between both groups of rocks.

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Trevor A. Jackson is Professor of Igneous Petrology in the Department of Geography and Geology, University of the West Indies, Mona, Jamaica.

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