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Stratigraphic Constraints on the Late Jurassic–Cretaceous Paleotectonic Interpretations of the Placetas Belt in Cuba

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ABSTRACT

The Placetas belt in north-central Cuba consists of Late Jurassic–Cretaceous rocks that were highly deformed during the Paleocene to middle Eocene arc-continent collision. The Late Proterozoic marble and Middle Jurassic granite are covered by the shallow-marine arkosic clastic rocks of late Middle Jurassic(?) or earliest Late Jurassic(?) ages. These arkosic rocks may be older than the transgressive arkosic deposits of the Late Jurassic–earliest Cretaceous Constancia Formation. The Berriasian age of the upper part of the Constancia Formation in some outcrops at Sierra Morena and in the Jarahueca area does not confirm the Late Jurassic (pre-Tithonian) age of all deposits of this unit in the Placetas belt. The Tithonian and Berriasian ammonite assemblages are similar in the Placetas belt of north-central Cuba and the Guaniguanico successions in western Cuba. We conclude that in all paleotectonic interpretations, the Placetas, Camajuaní, and Guaniguanico stratigraphic successions should be considered as biogeographically and paleogeographically coupled during the Tithonian and the entire Cretaceous. These successions could not have been separated by any large continental block and/or wide oceanic basin.

The Tithonian-Berriasian ammonite assemblages reported from the Placetas belt and coeval assemblages known in Mexico are different; in particular, *Suarites*, *Acevedites*, and *Kossmatia* (characteristic Mexican genera) are unknown from the Tithonian sections of the Placetas belt. Moreover, the Early Cretaceous and Cenomanian deep-water formations of the Placetas belt do not contain deposits symptomatic of a presence of a nearby large landmass (Chortis Terrane?) to the south. Dissimilarities existing between the Huayacocotla remnant and the Guaniguanico (and Placetas) successions in Cuba are not consistent with the conclusion of some authors that the Jurassic and Early Cretaceous successions in western Cuba are nearly identical to those of San Pedro del Gallo Terrane remnants in east-central

Mexico. Also, the composition of Late Jurassic ammonite and microfossil assemblages in western Cuba is not in agreement with the paleolatitudinal position of the Guaniguanico Terrane at ~30°N, close to the Pacific coast.

Many authors accept interpretations linking the Placetas succession with the southern slope of the Bahamas and/or with the Proto-Caribbean basin floor. However, the stratigraphic record strongly suggests that only the southernmost Tithonian deposits of the Placetas succession (Sierra de Camaján) may represent the basinal section accumulated on the Proto-Caribbean oceanic floor. The original proximity or even continuity of the Late Jurassic–Cretaceous Placetas and Camajuaní successions is probable on the basis of existing stratigraphic data.

INTRODUCTION

Major oil fields discovered in Cuba are connected with rocks of the Placetas fold and thrust belt (López et al., 1992). The Placetas belt in north-central Cuba (Figure 1A) consists of Late Jurassic–Cretaceous rocks (Figure 2) that were highly deformed during arc-continent tectonic convergence, with final collision in the Paleocene to middle Eocene (Gealey, 1980; Gordon et al., 1997; Pszczółkowski, 1994b, 1999). The Placetas belt is discontinously exposed south of the Bahamas Platform represented in Cuba by the Remedios and Cayo Coco zones (Pardo, 1975; Iturralde-Vinent, 1994). The Placetas belt presently is bounded on the south and partly covered by an ophiolitic complex and the Cretaceous volcanic-arc overthrust that occurred during the Paleogene collision. Thrust imbrication of the North American passive margin and northwestward overthrusting of an ophiolitic complex and arc rocks occurred in the late Paleocene–earliest Eocene, as evidenced by nannoplankton data from western Cuba (Bralower and Iturralde-Vinent, 1997). The Caribbean island arc, named the Great Arc (cf., Mann, 1999), was linked with the Pacific-derived Caribbean oceanic plate (Ross and Scotese, 1988; Pindell and Barrett, 1990; but see Frisch et al., 1992, Meschede et al., 2000, and Iturralde-Vinent, 1994, 1996, 1998). A clockwise rotation of maximum compressive stress direction in western Cuba was interpreted to reflect the diachronous collision of the Caribbean arc with the passive margin of North America during the latest Paleocene-early Eocene (Gordon et al., 1997; Hutson et al., 1998). It was proposed that the Cenozoic evolution of the northern Caribbean margin has been dominated by escape tectonics (Gordon et al., 1997). According to Pardo (1975), the interval of time from the Paleocene through the middle Eocene witnessed most of central Cuba's deformation. A major pulse of this collision occurred in the early to middle Eocene; this tectonic event could have culminated during the middle Eocene *Morozovella lehneri* Zone (Pszczółkowski and Flores, 1986). Berggren et al. (1995) calibrated this foraminiferal Partial Range Zone between 44 and 40 Ma. In the middle to late Eocene, a late phase of the arc-continent collision affected the Remedios and Cayo Coco platform zones (Iturralde-Vinent, 1998). In the northern Camagüey Province, the Cubitas overthrust of the serpentinitic mélange over the Remedios platform succession was active during the late middle Eocene (Iturralde-Vinent and Roque Marrero, 1982). Northeast of Sierra de Cubitas, the late Eocene Nuevitas Formation covers unconformably both the continental margin successions and the overthrust ophiolitic complex (Puscharovskiy et al., 1988).

The stratigraphy and tectonics of the Placetas belt were recognized as a result of surface geologic studies (Hatten et al., 1958; Ducloz and Vuagnat, 1962; Hatten, 1967; Meyerhoff and Hatten, 1968; Khudoley and Meyerhoff, 1971; Knipper and Cabrera, 1974; Meyerhoff and Hatten, 1974; Pardo, 1975; Kantchev et al., 1978; Pszczółkowski, 1983, 1986; Hatten et al., 1988) as well as works based on the subsurface data acquired from oil and gas wells (e.g., Kuznetsov et al., 1981; Fernández et al., 1992; Alvarez Castro et al., 1998; Hernández Rey et al., 1998; Rodríguez-Viera et al., 1998). These studies resulted in recognition of the Placetas belt as a deformed succession of mainly pelagic rocks deposited south of the Bahamas Platform (Figure 1A; see also Furrazola-Bermúdez et al., 1964; Khudoley and Meyerhoff, 1971; Pszczółkowski, 1987; Iturralde-Vinent, 1996). Iturralde-Vinent (1997) and Kerr et al. (1999, p. 1582) regarded the Placetas belt as representing the deposits of the Proto-Caribbean basin and "the old Caribbean basin sections," respectively. Therefore, these authors consider that the Placetas succession was laid down on the (oceanic) floor of the Proto-Caribbean basin.

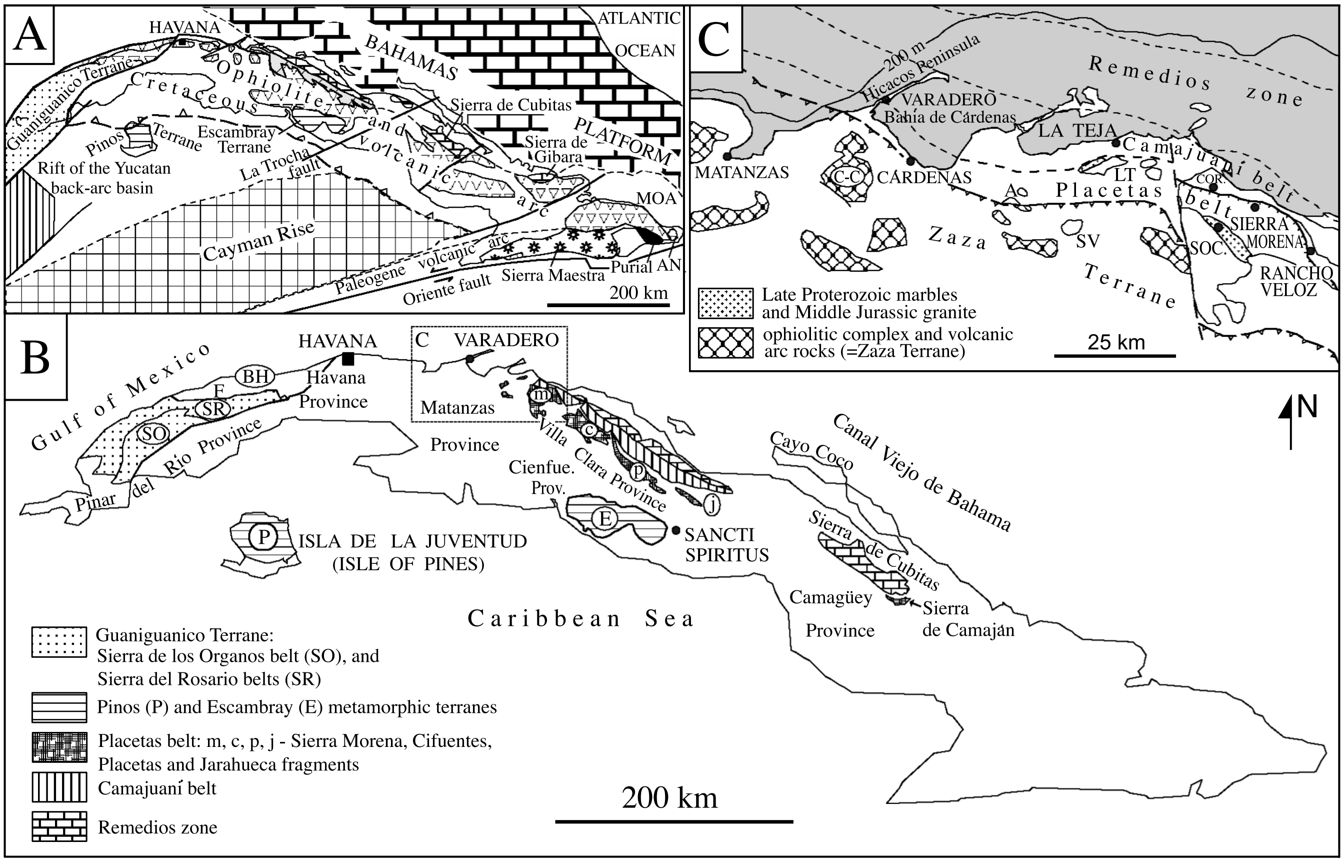

Figure 1. **(A) Tectonic scheme of Cuba and adjacent areas (partly after Iturralde-Vinent, 1998, and Rosencrantz, 1996): bricks = Bahamas Platform (Remedios and Cayo Coco zones in northern Cuba); diagonal lines (shaded) = Camajuaní and Placetas belts; horizontal lines = metamorphic terranes (Pinos, Escambray and Asunción— AN); inverted triangles = ophiolitic complex and Cretaceous volcanic arc rocks (=Zaza Terrane); asterisks = Paleogene volcanic arc in southeastern Cuba (Sierra Maestra); Purial = metamorphic (mainly amphibolitic) massif in southeastern Cuba; Cayman Rise (cross-hatched area) = volcanic arc (?); vertical lines = oceanic rift of the Yucatan back-arc basin; dashed line (with barbs) = southern tectonic boundary of the Cretaceous volcanic arc. (B) Location map of selected structures in central and western Cuba (compiled from Piotrowska, 1986; Pszczółkowski, 1983, 1986; Puscharovskiy et al., 1989): Cienfue. Prov. = Cienfuegos Province in south-central Cuba; F = Felicidades succession; BH = Bahía Honda area (westernmost part of the Zaza Terrane). (C) Enlarged fragment of the northern part of the Matanzas Province and northwestern Villa Clara Province (marked by rectangle in B): C-C = Cantel-Camarioca structural high; A = Amistad structural high; SV = El Sordo Viejo outcrop of the Early Cretaceous (Barremian) limestones of the Placetas succession; COR. = Corralillo; SOC. = Socorro.**

Although Hatten et al. (1988) named their Las Villas Unit (=Placetas belt) "a tectonostratigraphic unit," they did not express their opinion on the origin of this unit. Renne et al. (1989) concluded that Cuba is composed of tectonostratigraphic terranes juxtaposed during plate collision and subsequent transform motion between the Caribbean and North American plates in the late Mesozoic–Cenozoic. According to these authors, the Caribbean plate transported from the southwest fragments of an extensive Grenville-age belt that spanned the Americas during the Late Proterozoic. Sedlock et al. (1993) located their terrane named "central Cuba" (= Placetas succession) in southwestern and southern Mexico during the Middle Jurassic through earliest Cretaceous.

Pessagno et al. (1999, p. 123) claimed that "Jurassic and Early Cretaceous successions in western Cuba (Sierra del Rosario and Sierra de los Organos, Pinar del Río Province) show lithostratigraphic, paleobathymetric, and paleolatitudinal signatures which are nearly identical to those of San Pedro del Gallo terrane remnants in central Mexico." According to these authors, the Cuban remnants of the San Pedro del Gallo Terrane were carried from a paleolatitudinal position at ~30°N to eastern Yucatán by the Walper Megashear. Subsequent southwest-to-northeast movement of the Caribbean Plate during the Late

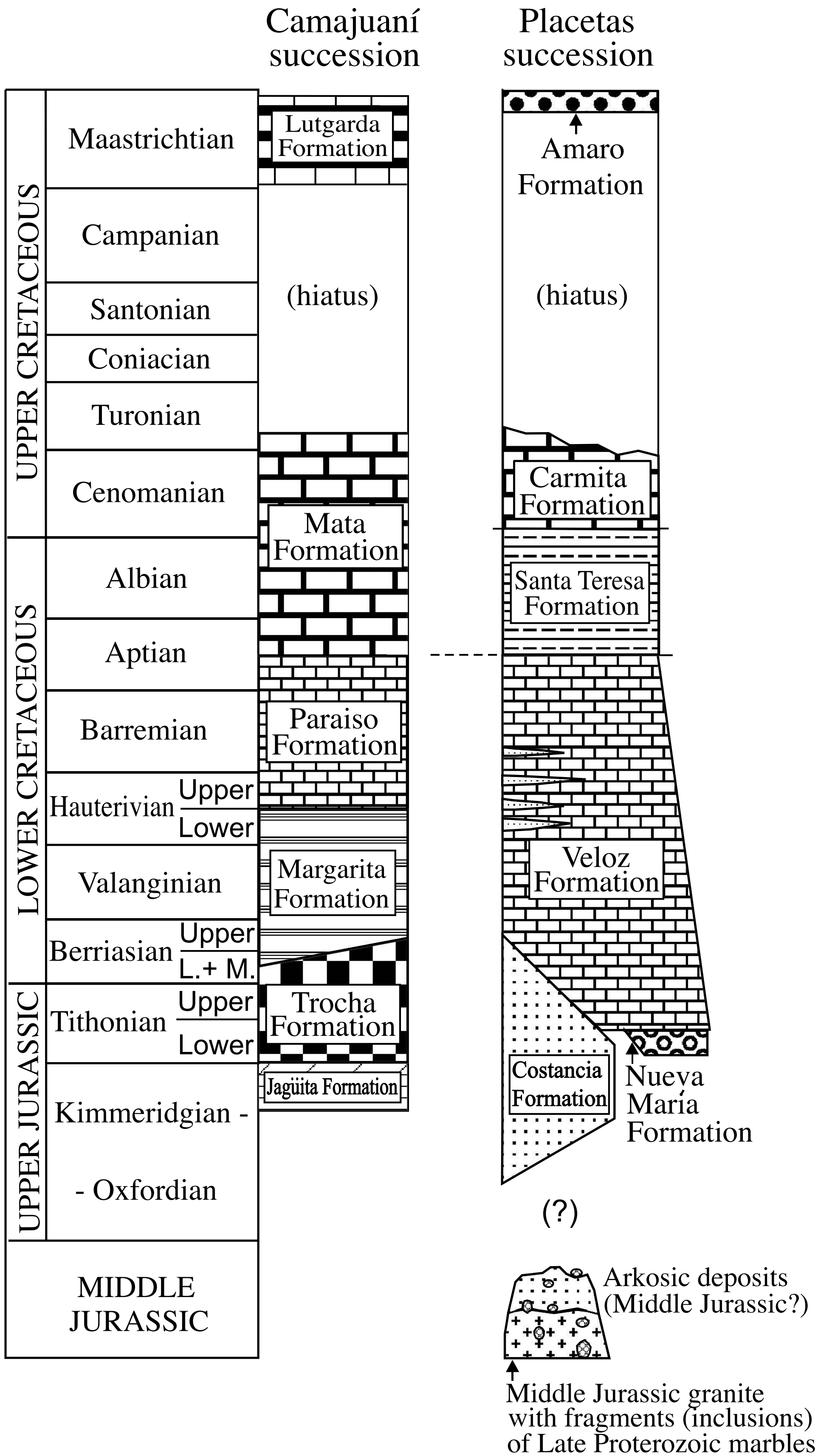

Figure 2. Generalized lithostratigraphy of the Placetas and Camajuaní successions in north-central Cuba. The Camajuaní succession (partly after Kantchev et al., 1978): Jagüita Formation = 50(?) m of dark-gray limestones, partly dolomitized; Trocha Formation = 150 to 400 m of gray radiolarian-calpionellid biomicrites, sometimes dolomitized, with interbeds of calcarenite and fine-grained calcirudite; Margarita Formation = 200 m of bedded micritic limestones, sometimes laminated, with interbeds of calcarenites and chert lenses or nodules; Paraiso Formation = as much as 220 m of thin-bedded micritic limestones, with interbeds of calcarenite and fine-grained calcirudite and chert layers or nodules; Mata Formation = 50 to 110 m of gray micritic limestones and light-brown marly limestones, with interbeds of calcarenites and calcirudites and gray-green or black radiolarian cherts and claystones; Lutgarda Formation = as much as 30 m of multi-colored limestones, mainly calcarenites and calcirudites, and red radiolarian cherts and calcareous claystones. The Placetas succession (after Kantchev et al., 1978; Pszczółkowski, 1986; Iturralde-Vinent and Marí Morales, 1988): Constancia Formation = 50 to 110 m of arkosic and polymictic sandstones, with interbeds of gray shales, siltstones, conglomerates, and limestone; Nueva María Formation = basalts and tuffites 62-m thick; Veloz Formation = 400–800 m of bedded gray to black micritic limestones and nannoplankton-radiolarian biomicrites with interbeds of calcarenites, cherts, sandstones, and shales; Santa Teresa Formation = as much as 150 m of radiolarian cherts with interbeds of shales, pelagic limestone, and, sometimes, turbiditic sandstones; the Carmita Formation = as much as 200 m of pelagic limestones, calciturbidites, silicified limestones, radiolarian cherts, nodular cherts, marls, and shales; Amaro Formation = breccia, massive calcarenite, and calcisiltite, of a total thickness of as much as 350 m.

Cretaceous and early Tertiary bulldozed the Cuban remnants of the San Pedro del Gallo Terrane into their present position.

The aims of our paper are as follows: (1) to present new stratigraphic data and recall the previously known stratigraphic records concerning the Late Jurassic to Late Cretaceous (Cenomanian-Turonian) deposits of the Placetas belt, and (2) to compare the contrasted paleotectonic interpretations with the available stratigraphic information.

LATE JURASSIC–LATE CRETACEOUS (TURONIAN) STRATIGRAPHY OF THE PLACETAS BELT

Location

The outcrops of Placetas stratigraphic succession occur in the northern part of central Cuba, from the Matanzas Province in the west to the Camagüey Province in the east (Figure 1B). The Placetas succession also is known from numerous wells drilled along the northern coast of Cuba in the Havana, Matanzas, and Villa Clara Provinces (Sánchez et al., 1989). In the northern Matanzas Province, the thrusted and folded fragments of the Placetas succession are known in some local structural highs (Piotrowska, 1986; Pszczółkowski, 1983). The Cantel-Camarioca structural high (Figure 1C) is the westernmost site where these rocks are exposed as thrusted limestones of the Veloz Formation (Piotrowska, 1986, Figure 3).

Figure 3. Late Proterozoic marble exposed south of the Cañas River and north of the Socorro locality.

These outcrops are located only a few kilometers south of the Varadero oil field (López Acosta and Socorro, 1998) that belongs to the Cuban Northern Oil Province (Echevarría-Rodriguez et al., 1991), which is about 1200-km long and 60–100-km wide (López et al., 1994). The Placetas belt is part of this petroleum province, which is characterized by a complex style of tectonic deformation (López Rivera, 1998). The Late Jurassic and Early Cretaceous to Cenomanian(?) carbonate and carbonate-terrigenic basinal rocks are the source rocks of hydrocarbons. Their considerable thickness resulted from tectonic repetitions (overthrusts) of the stratigraphic section. From the middle Eocene, generation of hydrocarbons was related strictly to the process of thrust-pile formation (López Rivera, 1998). The argillaceous deposits of Paleocene-early Eocene age (the Vega Alta Formation, mainly) provide an effective seal to the reservoirs (Pérez Estrada et al., 2001). The Varadero oil field, with more than 1500 million of barrels of petroleum *in situ,* is typical of this northern Cuban province (López Rivera, 1998). The Varadero oil is reservoired in the carbonate rocks of the Placetas succession. The Kimmeridgian shallow-water limestone and the Tithonian neritic to bathyal limestone are the major productive horizons in the western and central parts of the Cuban Northern Petroleum Province (Rodríguez-Viera et al., 1998). In the Jarahueca structure (Figure 1B) or fenster (Hatten, 1967), there is a minor reservoir producing light oil (Domínguez Garcés et al., 1998).

The main outcrops of the Placetas stratigraphic succession are located between Corralillo (northwestern Villa Clara Province) and the Sierra de Camaján in the Camagüey Province (Figure 1B). It was established from wells (López Acosta and Socorro, 1998) and outcrops (Pardo, 1975; Pszczółkowski, 1983) that the Placetas tectonic units structurally overlie the deformed Camajuaní succession. South of Corralillo and Sierra Morena, the outcrops of the Placetas belt are about 25-km wide (Figure 1C). In this area, the original tectonic structure of this belt, which is composed of relatively flat-laying thrust sheets, is well preserved (Pszczółkowski, 1983). In the Placetas belt, southeast of Rancho Veloz, Knipper and Cabrera (1974) distinguished three major ‘‘tectonic wedges’’ (named fragments in Figure 1B): Cifuentes, Placetas, and Jarahueca. The Sierra de Camaján outcrops of Placetas succession in the Camagüey Province form part of the allochthonous complex, together with the ophiolite and Cretaceous arc-volcanic rocks (Iturralde-Vinent and Marí Morales, 1988).

Figure 4. **The Paso de Guacalote breccia-conglomerate outcrop in the Cañas River.**

Pre-Late Jurassic Rocks and Their Arkosic Cover

Metamorphic rocks (marbles and quartzites) and granite are known to occur in the northwestern part of the Placetas belt near Socorro (south of Corralillo, Figure 1B) and also in the La Teja structural high (Hatten et al., 1958; Somin and Millán, 1977, 1981; Pszczółkowski, 1983, 1986). A white phlogopite-bearing marble was dated as Late Proterozoic (K-Ar dates published by Somin and Millán, 1977, 1981, and an $^{40}Ar/^{39}Ar$ plateau date of Renne et al., 1989), whereas the pink-colored granite was determined to be Jurassic in age (the whole-rock K-Ar ages of 139–150 Ma reported by Somin and Millán, 1977, and the U-Pb zircon date of an intrusive age of 172.4 Ma according to Renne et al., 1989). The skarn locally occurring in the Socorro area (Pszczółkowski and Millán, 1992) may be linked to the original contact zone between the marble and granite. At present, many of the marble blocks (Figure 3) rest on the outcropping granite or occur in the overlying arkosic deposits (Pszczółkowski and Millán, 1992). These deposits consist of sandstones and conglomerates; their arkosic material was derived from the nearby granite. Age of the discussed arkosic deposits is not determined, although it may be pre-Tithonian or even late-middle Jurassic(?). The Paso de Guacalote breccia-conglomerate (Figure 4) located in the Socorro area (Figure 1C) contains pebbles of volcanic and subvolcanic rocks (Figure 5), as well as metamorphic clasts (see also Somin and Millán, 1981, and Pszczółkowski and Millán, 1992). The Paso de Guacalote breccia conglomerate was considered to be of Late Cretaceous or Paleogene age (Somin and Millán, 1981), although this inference was not supported by any biostratigraphic or radiometric data. A fine arkosic conglomerate, also from the Socorro area, contains fragments of Late Proterozoic marble. This deposit is composed of quartz, feldspars, and rock fragments, with relatively common volcanic pebbles and some fragments of micritic and oolitic sandy limestones. Viewed in thin sections, the detritic matrix of this conglomerate contains bivalve shells, algae remains (Solenoporaceae), and echinoderm and bryozoan bioclasts. A sparse bivalve-echinoderm-algal-bryozoan assemblage may not be characteristic of the shallow-marine Late Cretaceous–Paleogene deposits, which are usually rich in rudistid debris and/or benthic foraminifers.

Geologic relations existing between the Late Proterozoic rocks, Middle Jurassic granite, and the formations of the Placetas succession (Oxfordian?–late Maastrichtian or K/T boundary, Figure 2) strongly suggest that the former rocks, with overlying arkosic deposits, occur as thrust slivers between the Placetas nappe sheets (Pszczółkowski, 1983, 1986; Pszczółkowski and Millán, 1992). Contrary to previous opinions (Pardo, 1975), indisputable stratigraphic contacts between the basement rocks, including their arkosic cover, and the Constancia Formation of the Placetas succession were not documented from the

Figure 5. **The Paso de Guacalote breccia-conglomerate; the dark-colored clasts are mainly volcanic rock fragments.**

outcrops nor from wells drilled in the Placetas tectonic units. Nevertheless, the arkosic deposits covering the Socorro granite and the arkosic sandstone and conglomerate occurring in the Constancia Formation (Oxfordian? to late Berriasian, Figure 2) are indeed similar in their abundant granitoid-derived clastic material.

East of the Socorro area, there are no unquestionable sialic basement outcrops in the Placetas belt. The report on the Quemadito Formation overlying the Tres Guanos quartz monzonite in the Jarahueca fenster (Hatten et al., 1958; Meyerhoff *in* Khudoley and Meyerhoff, 1971; Hatten et al., 1988) was challenged by other geologists (Kantchev et al., 1978; Somin and Millán, 1981).

In the Camagüey Province, the 62-m-thick middle Tithonian basalts and rocks named hyaloclastites and tuffites, assigned to the Nueva María Formation (Figure 2), are the oldest rocks exposed in the Sierra de Camaján below the limestones of the Veloz Formation (Iturralde-Vinent and Marí Morales, 1984, 1988). Iturralde Vinent and Marí Morales (1988) interpreted these basalts and other rocks to be deposited at the base of the continental slope and geochemically linked with the oceanic tholeiitic basalts.

LATE JURASSIC AND CRETACEOUS (BERRIASIAN-TURONIAN) FORMATIONS OF THE PLACETAS SUCCESSION

Constancia Formation

This formation, distinguished by P. Truitt in unpublished reports (cf., Pszczółkowski, 1986), consists of arkosic and polymictic sandstones (Table 1). The sandstone contains interbeds of siltstone, conglomerate, and limestone. Gray shale occurs at the base of some sections, and sandy limestone and marl also have been described (Kantchev et al., 1978).

In the Socorro area (Figure 1C), the sandstones and conglomerates consist mainly of granitoid-derived detritic material. In the Juarahueca structure, southeast of Quemadito (Figure 6), the coarse-grained arkosic sandstones (sample CP-34 in Figure 7) and sandstones to fine conglomerates (samples CP-37a and CP-37b in Figure 8) consist of feldspars, granitoid fragments, quartz, bioclastic limestone clasts (Figure 9), sparitic limestone fragments (Figure 10), and infrequent zircon and tourmaline grains. Clasts of quartz-mica schist (<1.5 mm) and polycrystalline quartz grains of metamorphic aspect also were observed. Echinoderm debris, thick-shelled bivalve fragments, and rare benthic foraminifers represent scarce bioclasts. A fine arkosic breccia in the uppermost part of the Constancia Formation (sample CP-37d in Figure 8) consists of quartz, feldspars, and frequent limestone clasts (Figure 11), mainly radiolarian and shallow-marine limestone fragments. Samples of arkosic sandstone to fine conglomerate collected at Quemadito (Figure 6) contain abundant rock fragments derived from granitoids, but also include clasts of quartz sandstone, quartzite, siliceous rocks, and sparitic and bioclastic limestone, as well as pieces of carbonized wood. Black, rounded grains of limestone and rare volcanic clasts also occur in these deposits.

Sandstone samples collected in the vicinity of Sierra Morena (Figure 1C) are composed mainly of granitoid-derived material but also contain frequent metamorphic clasts (schists and quartzites) and muscovite flakes.

Thus far, a direct link between the marble and granite of the Socorro–La Teja area (Figure 1C) with the Constancia Formation of the Placetas belt (Figure 2) was not demonstrated. The occurrence of these rocks in the deformed Placetas belt and the similar composition of (1) the arkosic deposits covering the Socorro granite and (2) the Constancia Formation clastics suggest— although do not demonstrate— an original depositional contact at the base of the latter unit. The facies characteristics of the compared deposits do not contradict the above-mentioned possibility. The shallow-marine arkosic clastics with scarce bivalve, echinoderm, algal, and bryozoan bioclasts could be replaced by transgressive, also shallow-marine, arkosic sandstones and conglomerates containing echinoderm and bivalve debris (the Constancia Formation).

The age of Quemadito Formation (= Constancia Formation) in the Jarahueca area was estimated to be Late Jurassic or older (Hatten et al., 1958). Furrazola-Bermúdez et al. (1979) recognized the deposits as being analogous to the Constancia Formation in deep wells drilled in the coastal area of the northern part of the Havana and Matanzas Provinces. These authors (Furrazola-Bermúdez et al., 1979) assigned a probable late Tithonian age to these Constancia-like deposits. On the basis of calpionellids, and taking into account ammonites found by V. Shopov (1975, and *in* Kantchev et al., 1978), the age of the Constancia Formation deposits exposed in the Sierra Morena area (Figure 1C) was assigned to the Tithonian–early Berriasian (Pszczółkowski, 1986).

In the oil fields located between Havana and Varadero (Figure 1B), Fernández et al. (1992) divided

Table 1. Stratigraphic synopsis of the Late Jurassic and Cretaceous (Berriasian-Turonian) formations of the Placetas succession (cf. Figure 2).

Formation	*Lithology and thickness*	*Boundaries*	*Age*	*Fossils*
Constancia	**Lithology**: arkosic and polymictic sandstones with siltstone, conglomerate, and limestone interbeds. **Thickness**: 50–110 m.	**Lower**: tectonic. **Upper**: transitional to the Veloz Formation.	Oxfordian (?)–Late Berriasian	Oxfordian(?) foraminifers (*Globuligerina* sp.; Díaz Collell, 1996), Tithonian ammonites (Shopov, *in* Kantchev et al., 1978); Berriasian calpionellids (Pszczółkowski, 1986 and this paper), radiolarians (this paper) and Early Cretaceous nannofossils (this paper).
Veloz	**Lithology**: gray to black micritic limestones and biomicrites with interbeds of calcarenite, chert, sandstone, and shale. **Thickness**: 400–800 m.	**Lower**: transitional to the Constancia Formation or the Nueva María Formation. **Upper**: transitional to the Santa Teresa Formation.	Tithonian-Aptian	Tithonian ammonites (Imlay, 1942; Shopov, 1975; Iturralde-Vinent et al., 1981), Berriasian calpionellids (de la Torre, *in* Piotrowska et al., 1981), nannoconids (this paper), Hauterivian-Barremian ammonites (Shopov, *in* Kantchev et al., 1978; Myczyński and Triff, 1986) and Aptian planktonic foraminifers (Pszczółkowski and Myczyński, 1999; this paper).
Santa Teresa	**Lithology**: radiolarian cherts with interbeds of shale, pelagic limestone and sandstone. **Thickness**: 100–150 m.	**Lower**: transitional. **Upper**: transitional to the Carmita Formation.	Aptian-Cenomanian	Scarce planktonic foraminifers (Kantchev et al., 1978).
Carmita	**Lithology**: pelagic limestone and radiolarian chert with interbeds of marl and shale. **Thickness**: 20–200 m.	**Lower**: transitional. **Upper**: erosional at the base of the Amaro Formation of the K/T boundary age.	Cenomanian-Turonian	Planktonic foraminifers and nannofossils (Kantchev et al., 1978; Pszczółkowski, 2000).

the Upper Jurassic part of the Placetas succession into five intervals, with the Oxfordian-Kimmeridgian as the oldest one. Four years later, Diaz Collell (1996) reported on the Oxfordian planktonic foraminifers identified as *Globuligerina* sp. (Table 1) from the Constancia Formation drilled in the Varadero–Bahía de Cárdenas oil field (Figure 1C). The Oxfordian to Kimmeridgian age of the Constancia Formation was accepted by various authors, mainly by petroleum geologists (e.g., Rodríguez-Viera et al., 1998, and Valladares Amaro et al., 1998). This age, however, was assigned by Alvarez Castro et al. (1998) to the Constancia Formation not only in the oil fields of the northern Havana and Matanzas Provinces, but in the entire Placetas belt in Cuba (cf., also Cobiella Reguera, 2000, Figure 7). Because all previous data and opinions concerning the younger (post-Kimmeridgian) age of the Constancia Formation deposits in some areas and/or tectonic units were omitted without any explanation and apparently are not represented in the proposed paleogeographic scheme (Alvarez Castro et al., 1998), we present herein data concerning the age of the Constancia Formation in some outcrops of north-central Cuba (Table 2). These

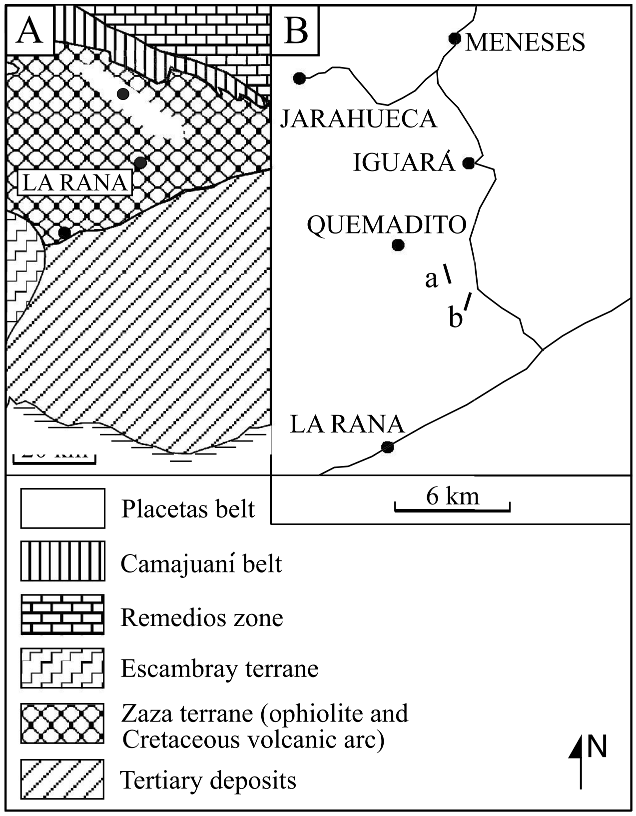

Figure 6. **(A) Position of the Juarahueca structure of the Placetas belt with respect to the main geological units of central Cuba (highly simplified). (B) Location of the sections of the Constancia and Veloz formations in the Jarahueca structure (situated close to the road from Iguará to La Rana): a = section shown in Figure 7; b = section shown in Figure 8.**

examples do not confirm the exclusively Late Jurassic (and even pre-Tithonian) age of all the deposits of the Constancia Formation in the entire Placetas belt. Rather, the diachronous character of the upper boundary of the Constancia Formation seems to be more pronounced in the various areas and/or tectonic structures of the Placetas belt (from Kimmeridgian? to late Berriasian) than previously recognized in the area located south of Corralillo and Sierra Morena (cf. Pszczółkowski, 1986).

Veloz Formation

The Veloz Formation originally was distinguished in the area of Rancho Veloz (Figure 1C); the type section of this formation was indicated 600 m to the north of this locality (Hatten, 1958; Hatten et al., 1958). Kantchev et al. (1978) gave a redefinition of this unit mapped in north-central Cuba (Kantchev et al., 1978; Piotrowska et al., 1981; Iturralde-Vinent et al., 1981). The Cifuentes, Ronda, Morena, and Fidencia Formations (Shopov, 1982; Kantchev et al., 1978) are partial equivalents of the Veloz Formation. The Cifuentes Formation (Tithonian) was distinguished only in the southernmost sections (Shopov, 1982) and is an equivalent of the lower part of the Veloz Formation. Currently, the Cifuentes Formation is used by petroleum geologists to denote the Kimmeridgian-Tithonian limestones in wells drilled along the northern coast of the Havana and Matanzas Provinces.

This thick formation (400–800 m in different tectonic units) consists of bedded gray to black micritic limestones and biomicrites with interbeds of calcarenites, cherts, sandstones, and shales (Table 1). South of Socorro (Figure 1C), thick-bedded, gray micritic limestones and fine calcarenites occur in the lowermost part of the Veloz Formation. These limestones, more than 20–30-m thick, include a fine calcirudite with coral and echinoderm bioclasts. In other sections, thick-bedded, black or gray limestones, sometimes dolomitized, occur directly above the Constancia Formation. These limestones probably correlate with the Cifuentes Formation of Shopov (1982). In general, the

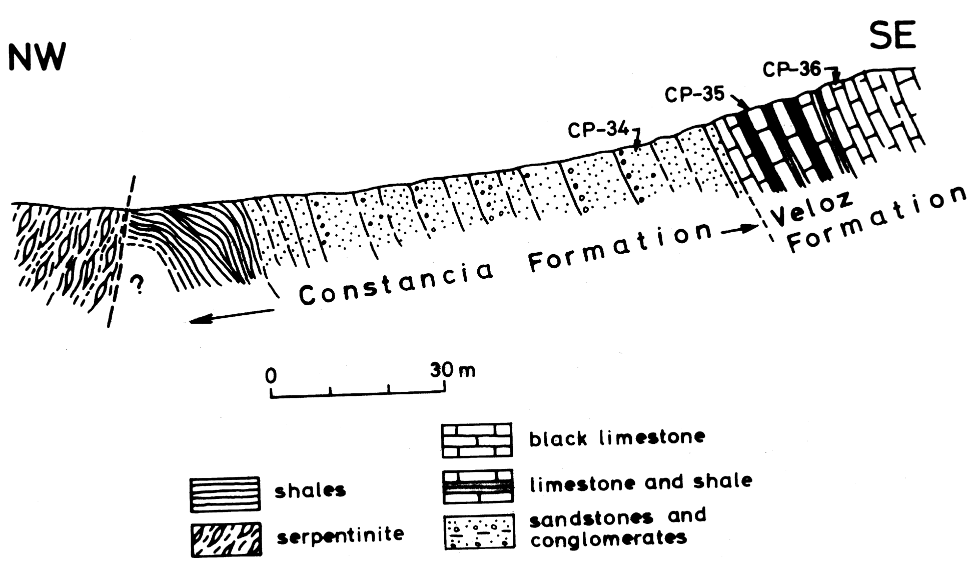

Figure 7. **Section of the Constancia Formation and lower part of the Veloz Formation located to the south of Iguará and Quemadito, in the southeastern part of the Jarahueca structure (a in Figure 6B); CP-34 through 36 denote samples described in the text (see also Table 2).**

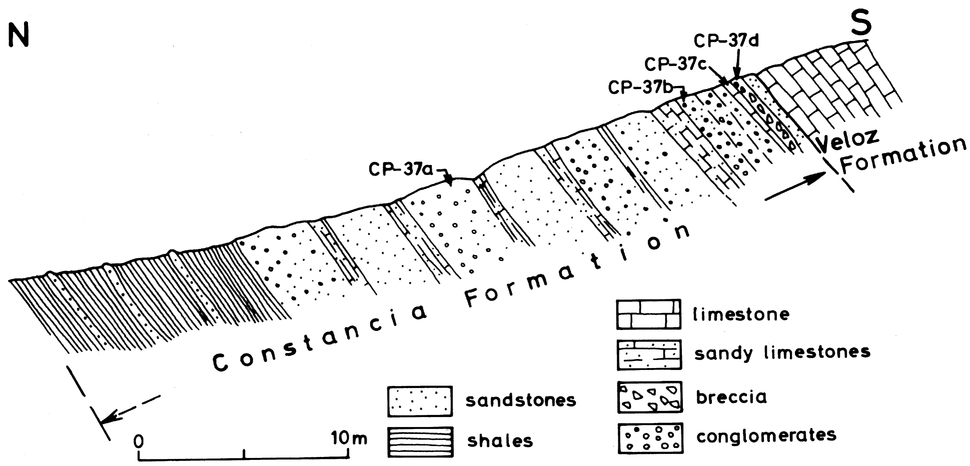

Figure 8. Section of the Constancia Formation and lowermost part of the Veloz Formation located to the south of Iguará and Quemadito, in the southeastern part of the Jarahueca structure (**b** in Figure 6B); CP-37a through 37d denote samples described in the text (see also Table 2).

pelagic nannoplankton-radiolarian limestones, sometimes dolomitized, are the main component of the Veloz Formation. Interbeds of turbiditic sandstone and siltstone of as much as 0.3 m that occur in the Hauterivian-Barremian to lower Aptian deposits in the western part of the Placetas belt (Pszczółkowski, 1982) are important for paleogeographical reconstructions (Pszczólkowski, 1999).

The age of the Veloz Formation is Tithonian-Aptian (Table 1). Ammonites and some calpionellids were reported from the Veloz Formation or its equivalents (Imlay, 1943; Pop, 1976; Kantchev et al., 1978; Iturralde-Vinent et al., 1981; Myczyński and Triff, 1986). Shopov (1975, and *in* Kantchev et al., 1978) identified several Tithonian ammonites in the lowermost part of the Veloz Formation. Pop (1976) found calpionellids of the *Calpionellopsis* Zone in samples collected south of Sierra Morena from "…gray and blackish micritic limestones crossed by numerous calcite diaclases…" (Pop, 1976, p. 245), probably belonging to the (lowermost?) Veloz Formation or its equivalent-named Ronda Formation. In thin sections consisting of radiolarian-calpionellid biomicrites collected in Sierra Morena and southwest of Socorro by the first author of the present paper (samples 3M-482 and 3M-592 in Table 2), A. de la Torre identified calpionellid taxa assigned to late Berriasian or early Valanginian ages (*in* Piotrowska

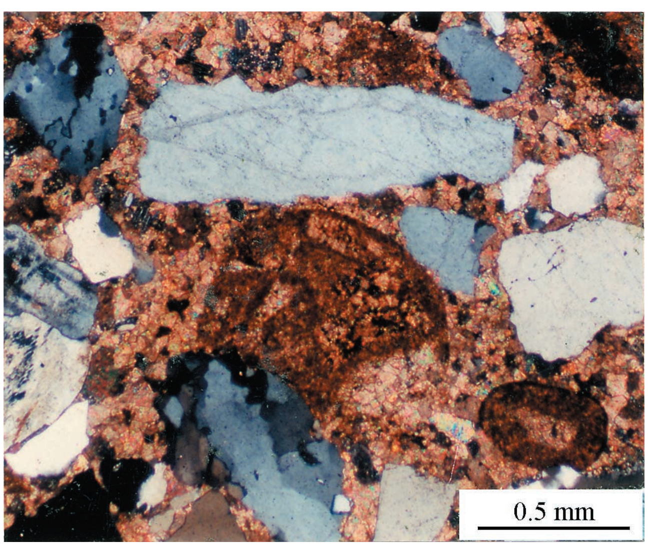

Figure 9. Light microscope (LM) photomicrograph of the coarse-grained arkosic sandstone from the Constancia Formation in the Jarahueca structure (sample CP-34 in Figure 7). Clast of a bioclastic limestone (840 μm across) containing crinoid debris is shown in the middle of the photomicrograph.

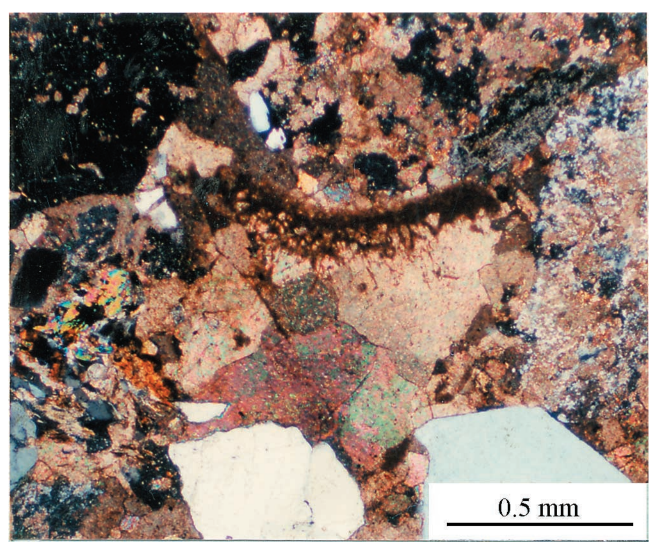

Figure 10. LM photomicrograph of the coarse-grained arkosic sandstone from the Constancia Formation in the Jarahueca structure (sample CP-37b in Figure 8). A sparitic limestone clast 1 mm across with iron-infilled borings (fungi or algae?) at the "upper" side is shown in the center.

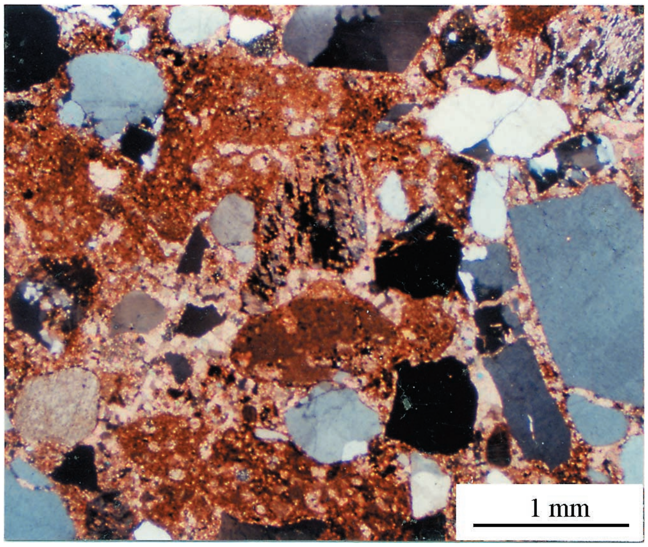

Figure 11. **LM photomicrograph of fine-grained breccia from the uppermost Constancia Formation in the Jarahueca structure (sample CP-37d in Figure 8). The breccia consists of feldspar grains, limestone clasts, and quartz grains.**

et al., 1981). These calpionellid data confirm that in the area of Sierra Morena, a transition from clastics of the Constancia Formation to the pelagic limestones of the Veloz Formation is late Berriasian in age[1]. Samples CP-35 and CP-36 collected from a lowermost limestone unit of the Veloz Formation (Figure 7) in the Jarahueca structure (Figure 6-A) also are Berriasian in age (Table 2). A. A. Meyerhoff (*in* Khudoley and Meyerhoff, 1971, p. 69) mentioned a presence of probable Early Cretaceous (Neocomian) limestones in the Jarahueca fenster. Our results confirm the validity of this information.

Iturralde-Vinent et al. (1981) and Iturralde-Vinent and Marí Morales (1988) reported a markedly different stratigraphic position of the lowermost strata of the Veloz Formation from the Sierra de Camaján in the Camagüey Province (Figure 1B). There, the Veloz Formation overlies the basalts, hyaloclastites, and "tuffites" of the middle Tithonian Nueva María Formation. Iturralde-Vinent et al. (1981) subdivided the lower part of the Veloz Formation into three lithologic units: (1) 30 m of micritic limestones, biomicrites, and tuffites with the calcareous shale interbeds of a middle Tithonian age, with *Chitinoidella cubensis* (Furrazola-Bermúdez, 1965), *Chitinoidella* sp., *Saccocoma* sp., and small ammonites (*Pseudolissoceras* spp., and *Virgatosphinctes*[?] sp.); (2) 40 m of micritic limestones, biomicrites, sometimes laminated, with occasional interbeds of calcareous shale of late Tithonian age; this unit contains numerous ammonites identified as *Protancyloceras hondense* Imlay (1942), *Vinalesites rosariensis* (Imlay), *Parodontoceras antilleanum* (Imlay), *P. butti* (Imlay), *Corongoceras* spp., *Himalayites (Micracanthoceras)* spp., *Hildoglochiceras* spp., *Haploceras* sp., and also aptychi, calpionellids, radiolarians, and *Globochaete alpina* Lombard; (3) about 50 m of laminated thin-bedded biomicrites with interbeds of black chert of Berriasian age, with uncoiled ammonites (*Leptoceras* sp.), calpionellids (*Calpionella elliptica* Lorenz, *Calpionellopsis* sp., *Tintinnopsella longa* [Colom]), radiolarians, and calcareous nannoplankton.

The second author of this paper was invited by M. A. Iturralde-Vinent to visit the Sierra de Camaján and thus was able to study ammonites in the field (see Myczyński, 1989) and also those collected from lithologic units (1–3) of this section that were deposited in the Institute of Geology and Paleontology (Cuba). Samples of ammonite-bearing limestone fragments (M-1 through 17) were thin-sectioned and studied under the light microscope. Fresh chips from four samples (C-3 through 6) obtained from M. A. Iturralde-Vinent (in 1985) also were examined under scanning electron microscope (SEM) for calcareous nannoplankton (mainly nannoconids). The results of this study are summarized in Table 3; on this basis, some additional data may be added to the stratigraphy of the Veloz Formation (lower part) in the Sierra de Camaján. In the twofold subdivision of the Tithonian stage, unit (1) of Iturralde-Vinent et al. (1981) corresponds to the upper part of the *Chitinoidella* Zone of late early Tithonian–earliest late Tithonian. We report occurrences of *Butticeras butti* (Imlay, 1942) and *B. antilleanum* (Imlay, 1942) in the lower Tithonian of the Sierra de Camaján section. The main part of unit (2) is late Tithonian in age, with *Salinites grossicostatum* (Imlay) and *S. gallardoi* (Chudoley and Furrazola-Bermúdez) reported by Myczyński (1989). The occurrence in the late Tithonian–early Berriasian limestones of some ammonite taxa typical of the Guaniguanico sections in western Cuba is confirmed herein. Our observations strongly suggest that the taxa *Protancyloceras hondense*, *P. catalinense,* and *Butticeras butti* disappeared in the early Berriasian. We have not observed well-preserved specimens of *Vinalesites rosariensis* (Imlay, 1942) in the studied samples; nevertheless, this taxon was previously reported by Iturralde-Vinent et al. (1981) and Myczyński (1989). Iturralde-Vinent et al. (1981) assumed that

[1] The *Calpionellopsis* Standard Zone, previously considered to be of Late Berriasian–earliest Valanginian age (Remane et al., 1986), recently has been restricted to the late Berriasian (Grün and Blau, 1997).

Table 2. Results of microfossil and nannofossil study of samples collected from the uppermost part of the Constancia Formation and the lower part of the Veloz Formation in north-central Cuba.

Samples	*Location*	*Microfossils*	*Nannofossils*	*Age*
3M-1412A, 3M-1412B	Sierra Morena (Figure 1C): marly biomicrite from the uppermost Constancia Formation.	*Calpionellopsis simplex*, *Cps. oblonga* (Figure 12A), *Calpionella alpina*, *C. elliptica* (?), *Tintinnopsella carpathica* (Murgeanu and Filipescu)	*Nannoconus steinmannii minor*, *N. steinmannii steinmannii*, *N.* gr. *steinmannii-colomii*	Late Berriasian (*Oblonga* Subzone of the *Calpionellopsis* Standard Zone; Remane et al., 1986)
3M-482	A biomicrite from the basal Veloz Formation, southwest of the Socorro locality (Figure 1C).	*Calpionella alpina*, *Calpionellopsis oblonga*, *Stenosemellopsis hispanica* (calpionellids identified by A. de la Torre, *in* Piotrowska et al., 1981)		Late Berriasian
3M-592	This sample was collected from folded limestones of the Veloz Formation (exposed near the Constancia Formation deposits) at Sierra Morena (Figure 1C).	*Calpionellopsis simplex* or *Calpionellites darderi* (calpionellid identified by A. de la Torre, *in* Piotrowska et al., 1981)		Late Berriasian or early Valanginian
CP-35	A biomicrite collected from the basal Veloz Formation (Figure 7) in the Jarahueca structure (Figure 6A).	**Calpionellids**: *Calpionella alpina* and ?*Calpionellopsis* sp. **Radiolarians**: *Archaeodictyomitra* sp., *Parvicingula* sp., ?*Napora* sp., and ?*Obesacapsula* sp.	*Nannoconus steinmannii steinmannii*, *N. steinmannii minor*, *N.* cf. *colomii*, *N.* gr. *steinmannii-colomii* (Figure 16) and *N.* sp. cf. *N. kamptneri kamptneri*.	Berriasian; not older than NJK-D Subzone of (late) early Berriasian (see Bralower et al., 1989).
CP-36	Black radiolarian biomicrite from the lower Veloz Formation collected 16 m above the sample CP-35 (Figure 7).	**Calpionellids**: *Calpionellopsis oblonga*. **Radiolarians**: *Crucella* sp., ?*Homoeoparonaella* sp. (Figure 13C), ?*Emiluvia* sp., *Hsuum* sp., *Eucyrtis* sp. cf. *E. micropora*, *Mirifusus* sp. cf. *M. baileyi*, *Obesacapsula* sp., *Parvicingula* sp., ?*Praeconocaryomma* sp., ?*Podobursa* sp., *Sethocapsa* sp. cf. *S. trachyostraca*.	*Nannoconus steinmannii steinmannii*, *N. steinmannii minor*, *N.* gr. *steinmannii-colomii*.	Late Berriasian
CP-37c	The Jarahueca structure (Figure 6A): biomicrite (Figure 13A) with some detritic grains of feldspar (Figure 14), uppermost Constancia Formation (Figure 8).	**Calpionellids**: ?*Salpingellina* sp.; **Radiolarians**: *Sethocapsa* sp. cf. *S. trachyostraca* Foreman, *Parvicingula* sp., ?*Hsuum* sp., ?*Loopus* sp., ?*Spongocapsula* sp., ?*Mirifusus* sp.	*Nannoconus globulus minor*, *N. globulus globulus*, *N. steinmannii steinmannii* (Figure 15), *N. kamptneri kamptneri*, *N.* cf. *colomii*, *Watznaueria barnesae*, *Watznaueria* sp.	Early Cretaceous (not older than late–early Berriasian; see Bralower et al., 1989)

the Tithonian/Berriasian boundary occurs between units (2) and (3). However, this chronostratigraphic boundary may be located, in fact, in the upper part of unit (2). Unit (3) is Berriasian in age, as recognized by Iturralde-Vinent et al. (1981). Our study, although based on limited material, suggests the presence of two Berriasian ammonite assemblages in the Sierra de Camaján section: the older one with *Protancyloceras catalinense, P. hondense, Salinites* sp., *Butticeras butti*(?), *Butticeras antilleanum*(?), ?*Neolissoceras* sp., and *Bochianites* sp. of early Berriasian age; and the younger one with ?*Protancyloceras* sp. of the late Berriasian. Specimens assigned to ?*Protancyloceras* sp. (Figure 18B) probably correspond to ?*Protancyloceras* sp. A, figured by Myczyński (1989) from Sierra de Camaján, although the characteristic hook-like arm is not visible in juvenile shells. Specimens of *Leptoceras* sp., reported by Iturralde-Vinent et al. (1981), were not found in our samples.

The ammonites also were reported from the Hauterivian-Barremian limestones of the Veloz Formation exposed in the northern Matanzas and northwestern Villa Clara Provinces (Myczyński *in* Piotrowska et al., 1981; Myczyński and Triff, 1986; Pszczółkowski and Myczyński, 1999). These ammonites also document Hauterivian and Barremian ages of the turbiditic sandstones occurring in the Veloz Formation exposures located in the western part of the Placetas belt (Pszczółkowski, 1982, 1999). V. Shopov (*in* Kantchev et al., 1978) identified various ammonites of Hauterivian and Barremian age found in the pelagic limestones of the Veloz Formation (= Fidencia Formation). In the northwestern part of the Villa Clara Province, the topmost beds of the Veloz Formation contain some planktonic foraminifers (Pszczółkowski and Myczyński, 1999). The foraminiferal assemblage is composed of the following taxa: *Blowiella* cf. *maridalensis* (Bolli), *Blowiella blowi* (Bolli) (Figure 12D), *Liliputianella* cf. *bizonae* (Chevalier), *L.* cf. *eocretacea* (Neagu), *L.* cf. *kuhryi* Longoria, *L.* cf. *longorii* Banner and Desai, *L. semielongata* (Longoria), *Praehedbergella sigali* (Moullade), *Leupoldina reicheli* (Bolli) (Figure 12E), and *Leupoldina* cf. *pustulans* (Sigal). This assemblage belongs to the Aptian *Leupoldina cabri* Zone (Longoria, 1974; Banner and Desai, 1988).

Santa Teresa Formation

This formation, distinguished by H. Wassall, is a well-known unit that is widely exposed in north-central and western Cuba (Kantchev et al., 1978; Iturralde-Vinent et al., 1981; Iturralde-Vinent and Marí Morales, 1988; Pszczółkowski, 1982, 1986, 1999). This formation also was reported from oil wells drilled in the northern Matanzas Province and in the offshore area (Kuznetsov et al., 1981; Hernández et al., 1998). The Santa Teresa Formation consists of radiolarian cherts with interbeds of shale, pelagic limestone, and, sometimes, turbiditic sandstones (Table 1). In many outcrops, these deposits are strongly folded. The Aptian-Cenomanian age of the Santa Teresa Formation in north-central Cuba (Figure 2) is based on (1) scarce occurrences of planktonic foraminifers (*Schackoina* sp., *Hedbergella* spp., *Clavihedbergella* sp., *Globigerinelloides* spp.) in limestone interbeds and (2) lithostratigraphic position of this unit. In the northwestern Villa Clara Province, the Santa Teresa Formation is not older than the Aptian *Leupoldina cabri* Zone, because the planktonic foraminifers of this age were found in the topmost beds of the underlying Veloz Formation (see above).

The radiolarian cherts of the Santa Teresa Formation are deep-water deposits accumulated at— and sometimes below— the calcite compensation depth. Occasional siliciturbidites reached the sea floor in the western part of the Placetas belt (Pszczółkowski, 1986).

Carmita Formation

The Carmita Formation (Figure 2) consists of pelagic limestones, calciturbidites, silicified limestones, radiolarian cherts, nodular cherts, marls, and shales (Table 1). In general, this formation is characterized by numerous limestone-chert intercalations. In some areas, the Carmita Formation also contains calcareous sandstone and siltstone interbeds. The Cenomanian-Turonian age of the Carmita Formation is based on the planktonic foraminifers, whereas ammonites were not found in this unit. Kantchev et al. (1978) reported about 20 species of planktonic foraminifers (identified by G. Furrazola-Bermúdez, A. de la Torre, and M. Stancheva), with *Schackoina cenomana* (Schacko), *Schackoina multispinata* (Cushman and Wickenden), *Hedbergella (=Whiteinella) brittonensis* Loeblich and Tappan, *Praeglobotruncana delrioensis* (Plummer), *Hedbergella (=Favusella) washitensis* (Carsey), *Rotalipora appenninica* (Renz), *R. reicheli* Mornod, *R. greenhornensis* (Morrow), and *Ticinella roberti* (Gandolfi). The bulk of the deposits assigned to this formation are Cenomanian in age. A sample collected from a limestone (biomicrite) bed at La Teja (northern Matanzas Province, Figure 1C) yielded the following

Table 3. Results of microfossil and nannofossil study of ammonite-bearing limestone samples from Sierra de Camaján, Camagüey Province in Cuba.

Sample	*Ammonites*	*Microfossils*	*Nannofossils*	*Age*
C-3	*Butticeras butti.*	*Calpionella alpina, Crassicollaria intermedia, Crassicollaria brevis, Crassicollaria* sp., *Tintinnopsella* sp., *Saccocoma* sp.	*Nannoconus wintereri, N.* cf. *wintereri, Cyclogelosphaera margereli, Ellipsagelosphaera britannica, Ellipsagelosphaera* sp., *Watznaueria barnesae.*	Late Tithonian *Intermedia* Subzone of the *Crassicollaria* Standard Zone (Remane et al., 1986); *Nannoconus wintereri* is indicative for the latest Tithonian (Bralower et al., 1989; Tavera et al., 1994).
C-4	*Protancyloceras catalinense, Salinites* sp. juv., *Bochianites* sp. juv.	*Calpionella alpina, Crassicollaria brevis, Cr. parvula, Cr.* gr. *intermedia-massutiniana, Tintinnopsella carpathica*	***Nannoconus kamptneri kamptneri, N. kamptneri minor, N. steinmannii minor*[1], *Watznaueria barnesae, W. barnesae, W. communis.***	Early Berriasian (cf. Pop, 1994); *Nannoconus steinmannii minor* Subzone (Bralower et al., 1989).
C-5	*Himalayites* (*Corongoceras*) *cordobai*[2].	*Calpionella alpina, Crassicollaria intermedia, Cr. brevis, Crassicollaria* sp., *Saccocoma* sp.	*Nannoconus* cf. *infans*[3], *N. wintereri*[4],*N.* cf. *wintereri, N.* gr. *wintereri-kamptneri minor, Ellipsagelosphaera ovata, Retecapsa*(?) sp.	Latest Tithonian (*sensu* Colloque, 1975; see also Remane et al., 1986; Grün and Blau, 1997; Zakharov et al., 1996); NJK-C nannofossil Subzone (Bralower et al., 1989).
C-6	*Butticeras butti* (?), ?*Neolissoceras* sp. juv.	***Calpionella alpina, Crassicollaria brevis(?), Cr. parvula, Crassicollaria* sp., *Tintinnopsella carpathica, Globochaete alpina.***	*Nannoconus* cf. *dolomiticus, N. wintereri, N.* cf. *wintereri, N.* gr. *compressus-infans, N.* sp. cf. *N. steinmannii minor, Ellipsagelosphaera* sp.	Early Berriasian *Calpionella alpina* Subzone of the *Calpionella* Standard Zone; NJK-C (upper part) or NJK-D Subzone (Bralower et al., 1989); NJK-D in scheme proposed by Tavera et al. (1994).
M-1	*Micracanthoceras* sp.	***Globochaete alpina.***	Not studied.	Late Tithonian (probably the earliest part).
M-2	?*Protancyloceras* sp.	*Calpionellopsis oblonga, Tintinnopsella carpathica.*	Not studied.	Late Berriasian *Oblonga* Subzone of the *Calpionellopsis* Standard Zone.
M-3	*Protancyloceras hondense.*	*Calpionella alpina, Crassicollaria* sp., Radiolaria.	Not studied.	Early Berriasian.
M-4	*Butticeras antilleanum* (?).	***Calpionellids***: *Calpionella alpina Crassicollaria ?parvula* **Radiolaria**: ?*Pantanellium* sp. ?*Loopus* sp.[5]	Not studied.	Early Berriasian *Calpionella alpina* Subzone of the *Calpionella* Standard Zone.
M-5	***Butticeras butti, B. antilleanum.***	*Saccocoma* sp.	Not studied.	Early Tithonian.
M-6	?*Bochianites* sp.	*Calpionella alpina and Radiolaria.*	Not studied.	Early Berriasian.

Table 3. Results of microfossil and nannofossil study of ammonite-bearing limestone samples from Sierra de Camaján, Camagüey Province in Cuba (cont.).

Sample	*Ammonites*	*Microfossils*	*Nannofossils*	*Age*
M-7	***Butticeras butti, B. antilleanum.***	*Saccocoma* sp. and Radiolaria.	Not studied.	Early Tithonian.
M-8	?*Protancyloceras* sp.[6]	*Calpionellopsis oblonga*[7], *Calpionellopsis simplex, Calpionella alpina, Tintinnopsella carpathica, Lorenziella* sp.,*Tritrabs* sp.[8]	Not studied.	Late Berriasian *Oblonga* Subzone of the *Calpionellopsis* Standard Zone.
M-9	?*Salinites* sp.	***Crassicollaria. brevis, Cr. Intermedia, Calpionella alpina, ?Conoglobigerina* sp.[9], *Saccocoma* sp., *Globochaete alpina.***	Not studied.	Late Tithonian.
M-10	?*Butticeras* sp.	*Chitinoidella* spp., *Saccocoma* sp.	Not studied.	Late–early Tithonian–earliest–late Tithonian (*Chitinolidella* Zone);
M-11	?*Butticeras* sp.	*Calpionella alpina, Crassicollaria intermedia, Chitinoidella* sp. , *Globochaete alpina,* Radiolaria.	Not studied.	Late Tithonian *Crassicollaria* Standard Zone.
M-12	*Protancyloceras hondense* (?)	*Calpionella alpina, Crassicollaria brevis, Cr.* gr. *intermedia-massutiniana, Crassicollaria* sp., Radiolaria.	Not studied.	Latest Tithonian(?) or earliest Berriasian.
M-13	*Butticeras antilleanum, Protancyloceras* sp.	*Calpionella alpina, Crassicollaria* sp., Radiolaria.	Not studied.	Late Tithonian (probably).
M-14	?*Protancyloceras* sp.	*Calpionellopsis oblonga, Calpionellopsis simplex, Tintinnopsella carpathica, Calpionella alpina.*	Not studied.	Late Berriasian *Oblonga* Subzone of the *Calpionellopsis* Standard Zone.
M-16	?*Bochianites* sp.	*Calpionella alpina, Crassicollaria brevis, Cr. intermedia* (?), *Crassicollaria* sp., Radiolaria.	Not studied.	Latest Tithonian (*Crassicollaria* Standard Zone, upper part); this sample may represent the earliest Berriasian *sensu* Tavera et al. (1994) and Olóriz et al. (1995).
M-17	***Butticeras butti,***	***Saccocoma* sp., *Globochaete alpina.***	Not studied.	Early Tithonian.

[1]*Figure 17;* [2]*Figure 18C (*Corongoceras cordobai *Verma and Westermann, 1973 is considered to be a late Tithonian taxon; cf.Verma and Westermann, 1973; Olóriz et al., 1999);* [3]*Figure 20;* [4]*Figure 19;* [5]*Figure 13D;* [6]*Figure 18B;* [7]*Figure 12B;* [8]*Figure 13B;* [9]*Figure 12C.*

planktonic foraminifers: *Costellagerina* cf. *libyca* (Barr), *Globigerinelloides* cf. *bentonensis* (Morrow), *Hedbergella* gr. *delrioensis-planispira*, *Praeglobotruncana* cf. *delrioensis* (Plummer), *P.* gr. *delrioensis-stephani*, *P.* cf. *gibba* Klaus, *Rotalipora* cf. *cushmani* (Morrow), *Schackoina* cf. *cenomana* (Schacko), *Whiteinella paradubia* (Sigal), *W.* cf. *archaeocretacea* Pessagno, *W.* cf. *baltica* Douglas and Rankin, and *W.* cf. *brittonensis* (Loeblich and

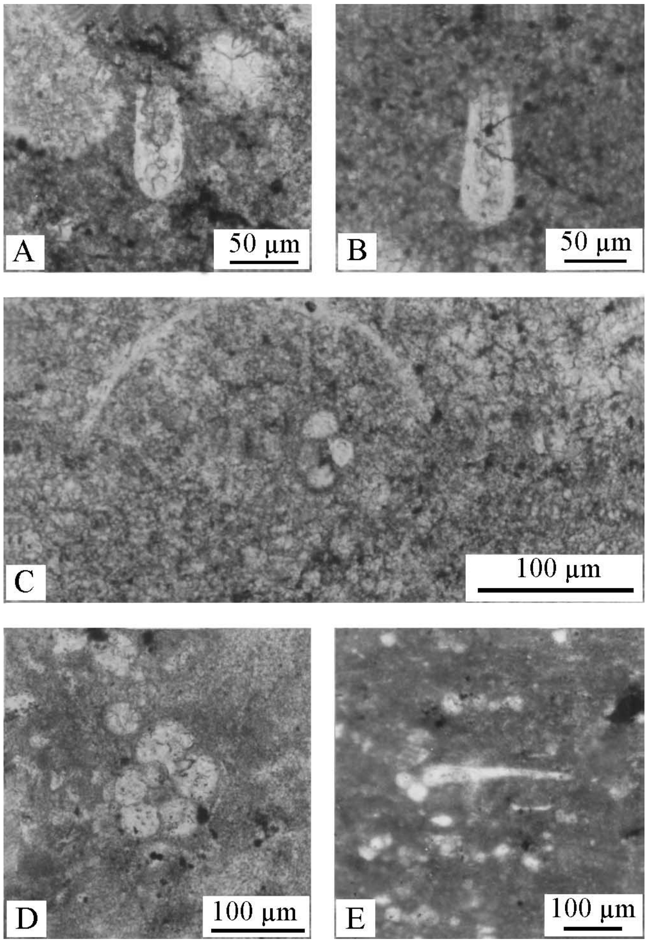

Figure 12. LM photomicrographs of calpionellids and planktonic foraminifers from the Tithonian-Aptian deposits of the Placetas succession in north-central Cuba. (A) *Calpionellopsis oblonga* (Cadisch), 1932 from sample 3M-1412-A in the uppermost part of the Constancia Formation, late Berriasian (Sierra Morena, Villa Clara Province; cf. Table 2). (B) *Calpionellopsis oblonga* (Cadisch), 1932 from sample M-8 of the Veloz Formation, late Berriasian, Sierra de Camaján in the Camagüey Province (Table 3). (C) ?*Conoglobigerina* sp. in a late Tithonian biomicrosparite (sample M-9) of the Veloz Formation (lower part) from Sierra de Camaján in the Camagüey Province (Table 3). (D) *Blowiella blowi* (Bolli), 1957 from sample 3M-235-A of the uppermost Veloz Formation, Aptian *Leupoldina cabri* Zone, northwestern Villa Clara Province in north-central Cuba. (E) *Leupoldina reicheli* (Bolli), 1957, also from sample 3M-235-A of the uppermost Veloz Formation (location as for D).

Tappan). This assemblage was assigned to the uppermost *Rotalipora cushmani* Zone of late Cenomanian age (Pszczółkowski, 2000).

As in western Cuba (cf. Pszczółkowski, 1999), the deep-water limestones, radiolarian cherts and turbidites of the Carmita Formation in the Placetas belt were laid down in a bathyal zone between the aragonite compensation depth and calcite compensation depth.

PALEOTECTONIC INTERPRETATIONS OF THE PLACETAS BELT IN THE LIGHT OF STRATIGRAPHIC DATA

Stratigraphic Data Common to the Placetas Belt and the Guaniguanico Successions in Western Cuba

A general similarity between the Cretaceous deposits in the Placetas belt of north-central Cuba (Figure 2) and the Northern Rosario belt, western Cuba (Figure 21A) was observed previously (Pszczółkowski, 1978). Now, this observation may be supported by the results of recent studies.

1) The Oxfordian to Kimmeridgian(?) planktonic foraminifers (*Globuligerina* sp.) were reported from

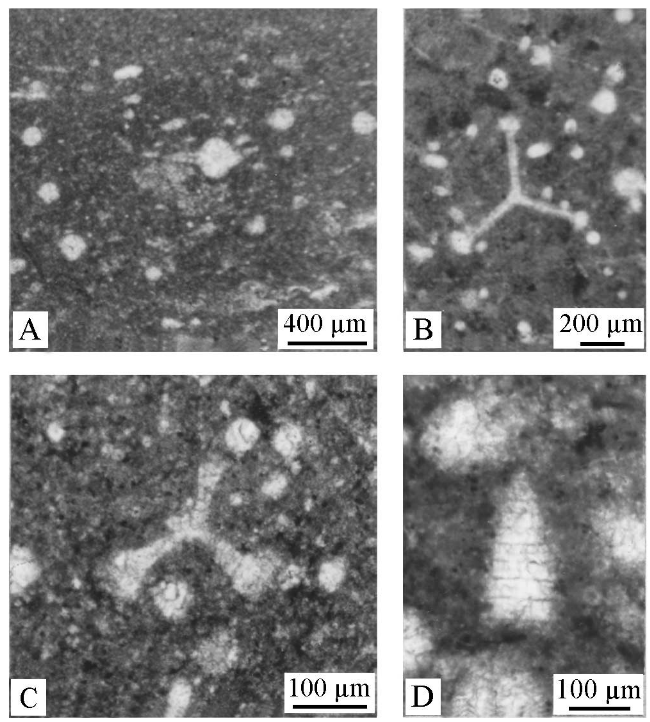

Figure 13. Radiolarians from the earliest Cretaceous limestones of north-central Cuba (LM photomicrographs). (A) Radiolarian-nannofossil biomicrite (sample CP-37c) from the uppermost part of the Constancia Formation, Berriasian, Jarahueca structure. (B) *Tritrabs* sp.; sample M-8 from the Veloz Formation, late Berriasian, Sierra de Camaján in the Camagüey Province. (C) ?*Homoeoparonaella* sp.; sample CP-36 from the lower part of the Veloz Formation, late Berriasian, Jarahueca structure. (D) ?*Loopus* sp.; sample M-4 from the lower part of the Veloz Formation, early Berriasian, Sierra de Camaján in the Camagüey Province.

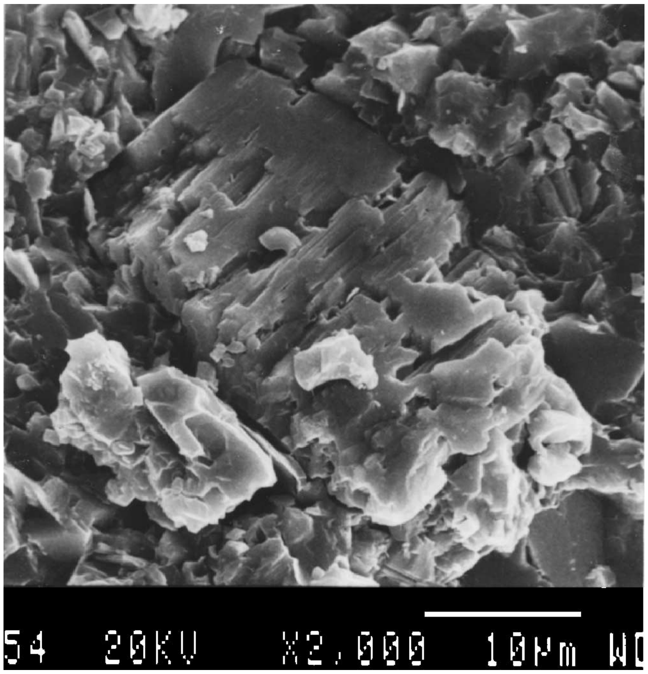

Figure 14. SEM photomicrograph showing detritic grain of plagioclase in a nannofossil-radiolarian biomicrite (*Nannoconus* sp. is visible at the right margin of the photomicrograph); sample CP-37c from the uppermost part of the Constancia Formation (Berriasian) exposed in the Jarahueca structure of north-central Cuba.

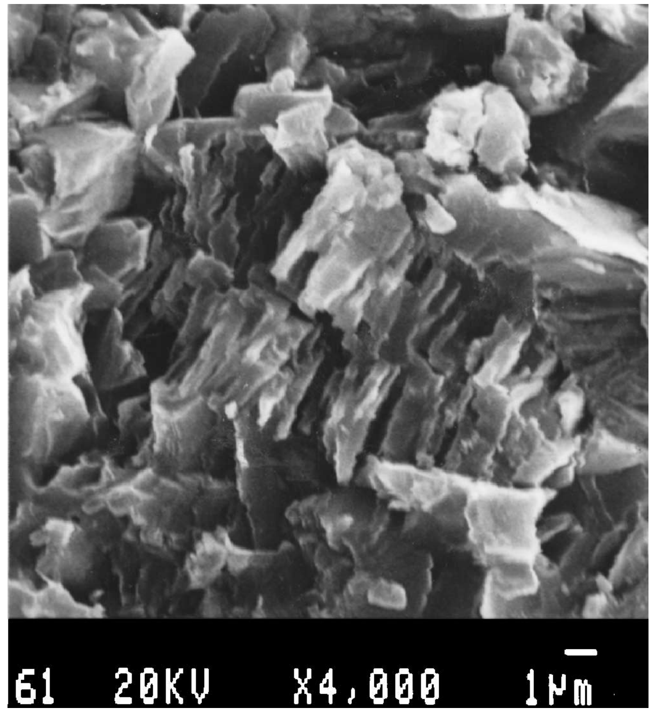

Figure 15. *Nannoconus steinmannii* Kamptner, 1931 subsp. *steinmannii* Deres and Achéritéguy, 1980 (SEM photomicrograph); sample CP-37c from the uppermost Constancia Formation (Berriasian) exposed in the Jarahueca structure of north-central Cuba.

the Constancia Formation in the Varadero–Bahía de Cárdenas oil field in the Matanzas Province (Díaz Collell, 1996). To our knowledge, planktonic foraminifers of this age have not been recognized thus far in outcrops of the Constancia Formation. Only a single specimen of ?*Conoglobigerina* sp. was found in late Tithonian limestone of the Veloz Formation from the Sierra de Camaján in the Camagüey Province (Figure 12C; Table 3). In Cuba, the first Late Jurassic planktonic foraminifers were reported from the Pimienta Member of the Jagua Formation in the Sierra de los Organos succession (Figure 21-A) of the Pinar del Río Province (Torre, 1988). These foraminifers were identified as *Globigerina (Eoglobigerina)* cf. *oxfordiana* Grigelis, and *Globigerina (Gubkinella)* sp. The species *G. (Eoglobigerina) oxfordiana* was assigned to the genus *Globuligerina* Bignot and Guyader, emended (Banner and Desai, 1988).

2) Although Oxfordian ammonites are numerous in some lithostratigraphic units of the Guaniguanico successions in western Cuba, they are unknown from the Placetas belt. Kimmeridgian ammonites were not reported from the Placetas belt or from the Guaniguanico Terrane. Tithonian ammonites found in the Placetas belt of north-central Cuba, and in the Sierra de Camaján, Camagüey Province, are listed in Table 4. These ammonites are closely related to those described from the Camajuaní stratigraphic succession (Figure 2), also in north-central Cuba (Figure 1), by Imlay (1942) and reported, although unpublished, by Shopov (1975). In this succession, the ammonites occur in the Trocha Formation and its equivalents (Kantchev et al., 1978). Nevertheless, the uppermost part of the Trocha Formation correlates with the uppermost part of the Caguaguas Formation (Pop, 1976, 1986) and is early to late Berriasian in age (Figure 2). Therefore, some of the ammonites reported from the Tithonian strata in the Camajuaní belt (Table 4) may come, in fact, from Berriasian strata[2]. A. de la Torre (*in* Kantchev et al., 1978) found Berriasian calpionellids in the "Meneses Formation" (=Trocha Formation). The first author of this paper found late Berriasian calpionellids in the Sierra de Meneses, southeast of Meneses (Figure 6B), in limestones assigned to the Meneses Formation by Shopov (*in* Kantchev et al., 1978).

[2] For example, the ammonite taxa: *Substeueroceras* spp., *Spiticeras* (*Spiticeras*) sp., and probably *Uhligites* sp.

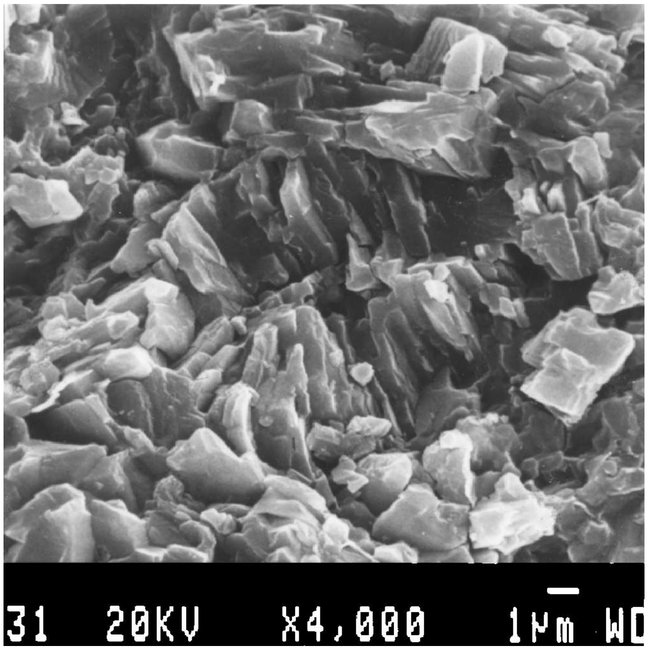

Figure 16. *Nannoconus* **gr.** *steinmannii-colomii* **(SEM photomicrograph); sample CP-35 from the lowermost part of the Veloz Formation (Berriasian) exposed in the Jarahueca structure of north-central Cuba.**

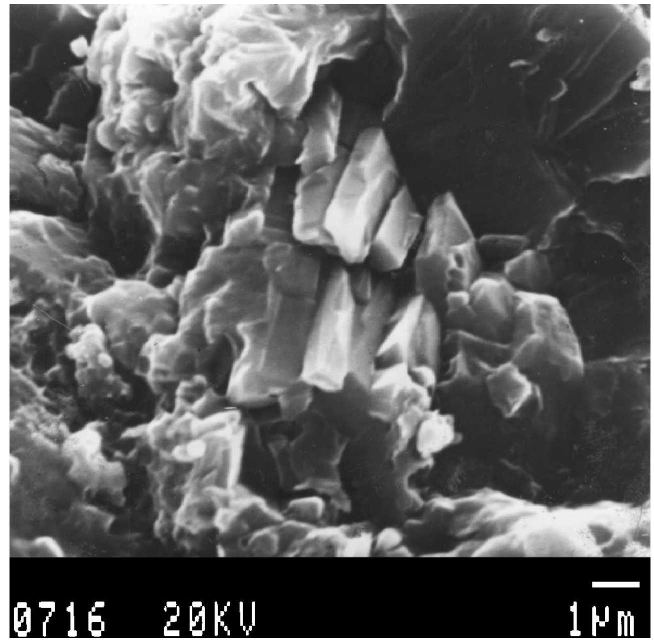

Figure 17. *Nannoconus steinmannii* **Kamptner, 1931 subsp.** *minor* **Deres and Achéritéguy, 1980 (SEM photomicrograph); sample C-4 from the Veloz Formation, early Berriasian, Sierra de Camaján, in the Camagüey Province.**

The ammonite assemblages of the Placetas belt are similar, as well, to those described from the Late Jurassic–earliest Cretaceous limestones of the Guaniguanico Terrane in western Cuba (Imlay, 1942, 1980; Judoley and Furrazola-Bermúdez, 1968; Myczyński, 1989, 1994a, 1994b, 1999b; Myczyński and Pszczółkowski, 1990, 1994). The most characteristic taxa described from the formations exposed in the Guaniguanico sections, e.g., *Butticeras butti, B. antilleanum, Protancyloceras hondense, P. catalinense, Vinalesites rosariensis, Paralytohoplites carribeanus, Salinites* spp., *Himalayites (Corongoceras), Mazapilites* spp., and *Pseudolissoceras* sp. also were found in the Placetas belt. The genus *Butticeras* Houša and Nuez, 1973 is typical of the Tithonian ammonite assemblages of the Placetas and Guaniguanico successions, with the first appearance of its two species (*B. butti* and *B. antilleanum*) in early Tithonian strata (Houša, 1974; Myczyński and Pszczółkowski, 1994; this paper). Their last occurrences are recognized herein in the early Berriasian deposits of the Sierra de Camaján (Camagüey Province). In the Sierra de los Organos belt of the Guaniguanico Terrane, "*Parodontoceras*" sp. (= *Butticeras* sp.) also was reported from early Berriasian limestones (Myczyński and Pszczółkowski, 1990).

The uncoiled ammonites— *Vinalesites rosariensis* (Imlay, 1942) and *Protancyloceras hondense* (Imlay, 1942)— have been reported from (late) early Tithonian up to early Berriasian strata in the Sierra del Rosario (Myczyński, 1977; Pszczółkowski, 1978; Myczyński and Pszczółkowski, 1994). In the Sierra de los Organos, these taxa were assigned to the Tithonian (Imlay, 1942; Judoley and Furrazola-Bermúdez, 1968; Myczyński, 1989, Figure 15; Myczyński and Pszczółkowski, 1990). However, in this belt, *V. rosariensis* and *P. hondense* seem to be found in Berriasian limestones, which is strongly suggested by an associated calpionellid assemblage reported from the strata referred to above in the Hacienda El Americano section (Pop, 1976; A. de la Torre *in* Myczyński, 1989, p. 55). In this section, located in the easternmost part of the Sierra de los Organos (Myczyński, 1989, Figure 1), the Tithonian/Berriasian boundary[3] probably is situated in the limestones with *Salinites*, below the strata with *Protancyloceras hondense* and *Vinalesites rosariensis* (Houša, 1974; Myczyński, 1989). Consequently, the early Berriasian limestones of the topmost part of the El Americano Member (cf. Myczyński, 1989, Figure 5) are about 8-m thick in the Hacienda El Americano section (Figure 21B). In the Valle del Ancón

[3] Placed at the base of the *Calpionella* Zone, or B calpionellid Zone (Zakharov et al., 1996). This boundary however, may not coincide with the base of the Mediterranean *Jacobi* Zone (cf. Tavera et al., 1994).

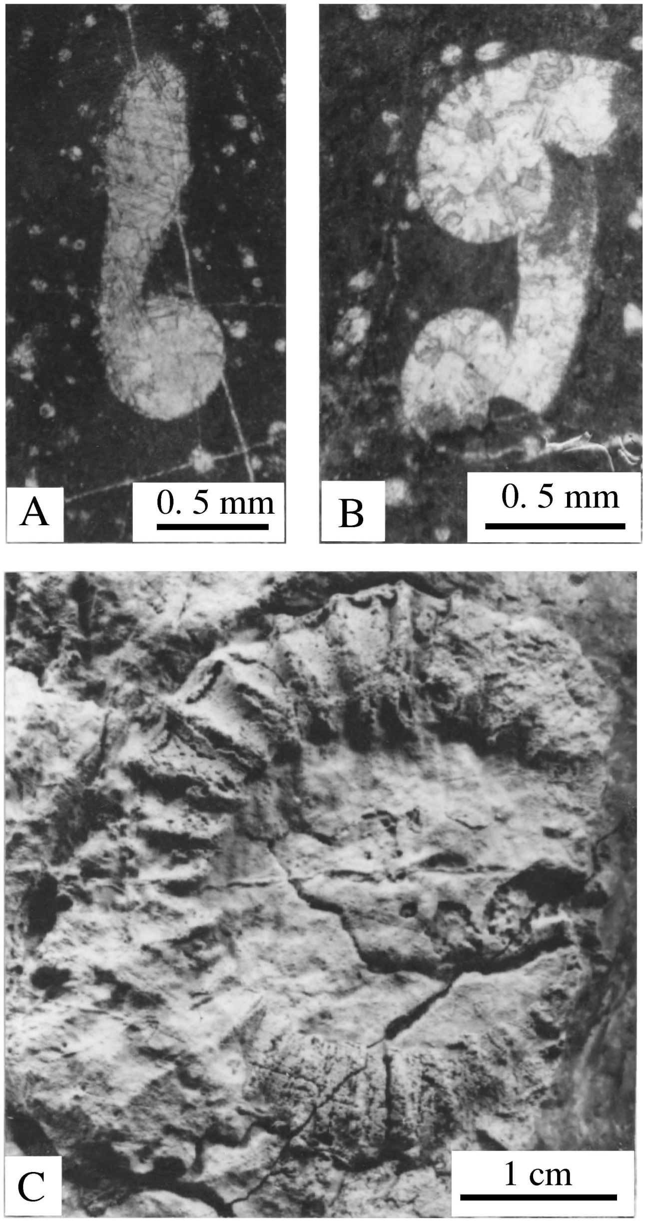

Figure 18. **Ammonites from the Guasasa Formation, western Cuba (A) and the Veloz Formation, Placetas succession, Sierra de Camaján, in the Camagüey Province (B, C): A = ?*Protancyloceras* sp. (juvenile form 1.6 mm in length cut in thin section); sample AP-25, Tumbadero Member of the Guasasa Formation, late Berriasian, Sierra de los Organos, Pinar del Río Province; B = ?*Protancylo-oceras* sp. (juvenile forms cut in thin section; the larger specimen is 1.3 mm in length); sample M-8 from the Veloz Formation, late Berriasian; C = *Himalayites* (*Corongoceras*) *cordobai* Verma and Westermann, 1973; sample C-5 from the Veloz Formation, late Tithonian, Sierra de Camaján, Camagüey Province.**

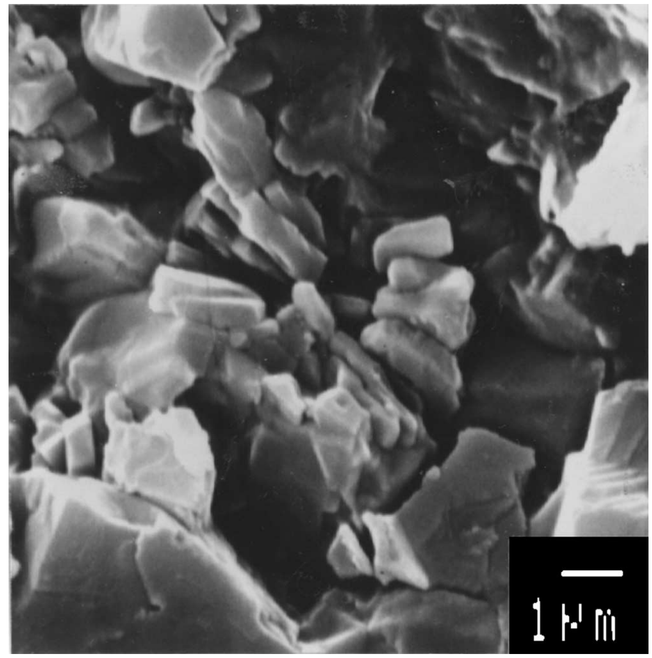

Figure 19. ***Nannoconus wintereri* Bralower and Thierstein, 1989 (SEM photomicrograph); sample C-5 from the late Tithonian limestone of the Veloz Formation exposed in the Sierra de Camaján, Camagüey Province.**

section (Myczyński, 1989, Figure 1), the position of the Tithonian/Berriasian boundary is less constrained. It is located at the base or at the top of a 0.55-m-thick limestone bed with *Salinites* spp., *Durangites* sp. aff. a*canthicus* Burckhardt, *Kossmatia* cf. *bifurcata* (Aguilera), *Phanerostephanus* sp., and *Haploceras*(?) spp. (cf. Myczyński, 1989, p. 50–51). This limestone bed also contains poorly preserved calpionellids (*Calpionella alpina* Lorenz, *Crassicollaria parvula* Remane, *Crassicollaria* sp., and *Tintinnopsella carpathica*? [Murgeanu and Filipescu]). The topmost limestone beds (4-m thick) of the El Americano Member occurring in the Valle de Ancón section have poorly preserved *Salinites* sp. (Myczyński, 1989, p. 50–51), and actually are early Berriasian in age. In the Sierra del Infierno section (Pszczółkowski, 1978, Figure 8), the topmost (about 6-m-thick) beds of the El Americano Member contain the following calpionellids (sample 6P-130): *Calpionella alpina* Lorenz, *Crassicollaria parvula* Remane, *Cr. brevis* Remane, and *Tintinnopsella carpathica* (Murgeanu and Filipescu). Therefore, the topmost limestone beds of the El Americano Member in the Sierra del Infierno section are earliest Berriasian in age. Thus, we confirm an earlier suggestion (Myczyński, 1989, p. 55) that the limestones of the uppermost part of the El Americano Member are early Berriasian in age (Figure 21A), at least in the sections mentioned above. Apparently different stratigraphic occurrences of *Vinalesites rosariensis* and *Protancyloceras hondense* recorded in two adjacent Guaniguanico successions possibly are associated with facies-related causes such as, for example,

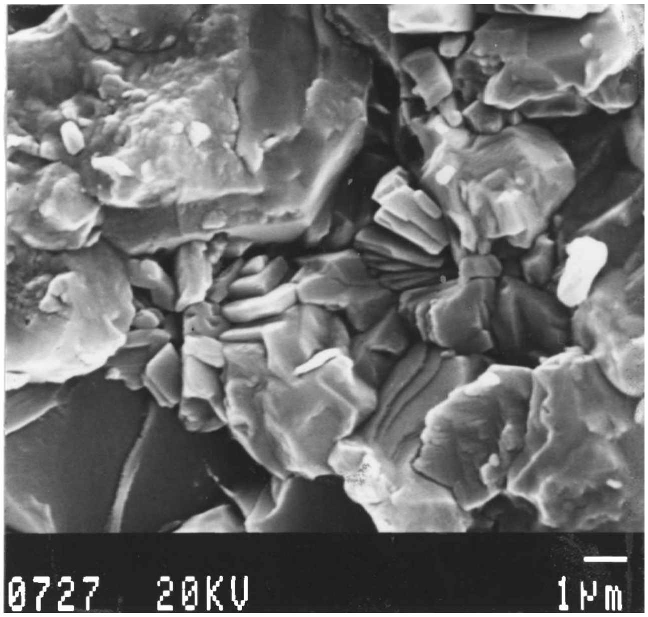

Figure 20. ***Nannoconus* cf. *infans* Bralower, 1989 (SEM photomicrograph); sample C-5 from the Late Tithonian limestone of the Veloz Formation exposed in the Sierra de Camaján, Camagüey Province.**

contrasted paleobathymetry during the Tithonian, although incomplete sampling of the El Americano Member limestones cannot be disregarded.

There are differences concerning frequency of some ammonites, as well as occurrence of a few less common taxa in the Placetas and Guaniguanico successions. For example, *Windhauseniceras internispinosum* (Krantz), reported by Shopov (1975, and *in* Kantchev et al., 1978) from the Placetas belt (Table 4), was not found in the Guaniguanico successions. Moreover, early Tithonian ammonites are less numerous in the Placetas belt in comparison with the coeval Guaniguanico fauna, mainly because of contrasted facies development of the Late Jurassic deposits in comparable tectonostratigraphic units.

3) Berriasian ammonites are infrequent or scarce in the Placetas belt and also in the Guaniguanico Terrane coeval limestones, particularly those of late early Berriasian and late Berriasian age. Three ammonite assemblages are distinguished in the Berriasian limestones of the Sierra del Rosario (Guaniguanico Terrane): (I) *Salinites* spp., sometimes with other taxa;

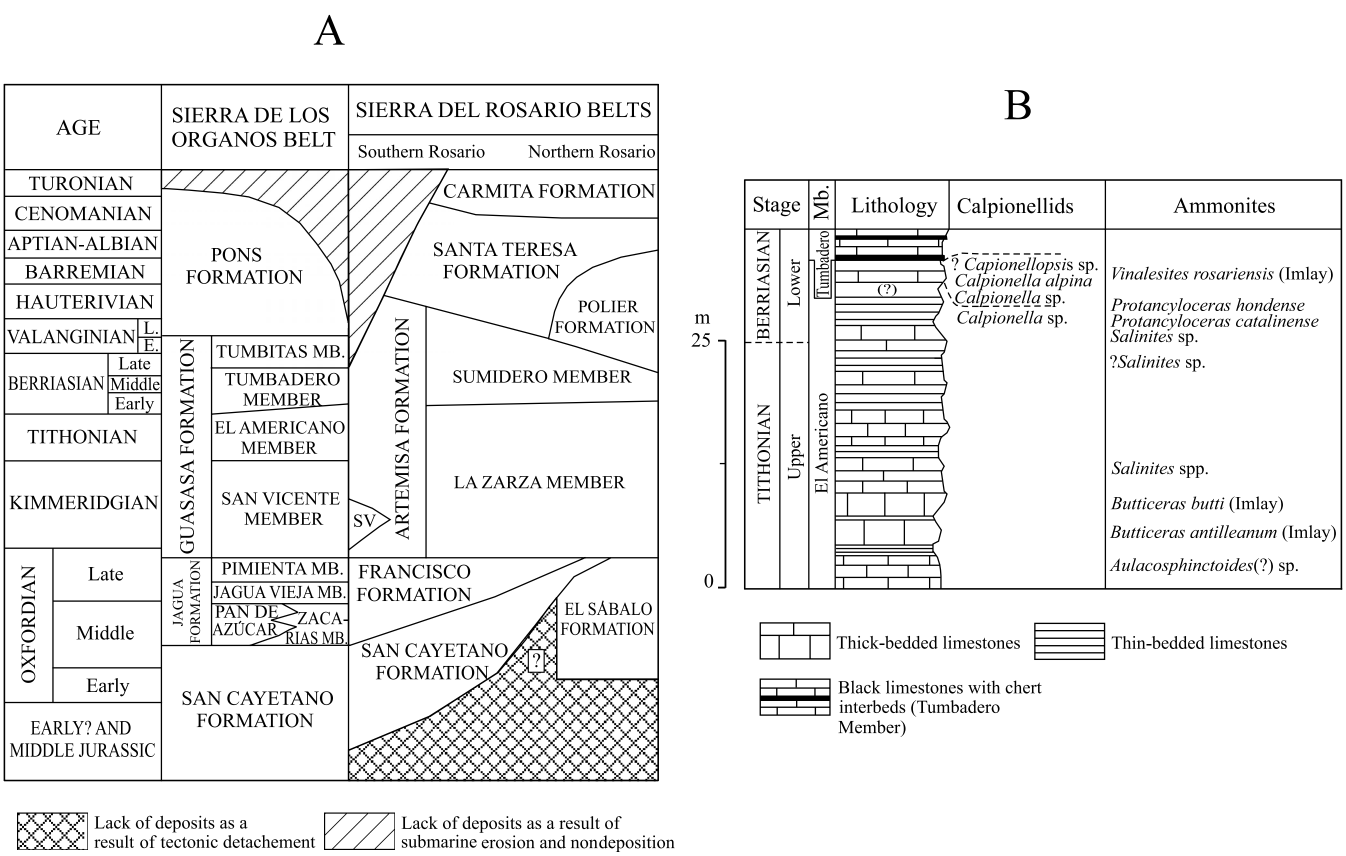

Figure 21. **(A) Jurassic–Late Cretaceous successions of the Guaniguanico terrane, western Cuba (after Pszczółkowski, 1999, modified). (B) The Tithonian/Berriasian boundary and the lithostratigraphic units in the Hacienda El Americano section, easternmost part of the Sierra de los Organos (partly after Myczyński, 1989).**

Table 4. Tithonian-Berriasian ammonites reported from the Placetas and Camajuaní belts in Cuba and from the east-central Mexico.

Stages	**Placetas belt (north-central Cuba),** Villa Clara, Sancti Spiritus, and Camagüey Provinces (Imlay, 1942; Shopov, 1975; Iturralde-Vinent et al., 1981; Myczyński, 1989; this paper).	**Camajuani belt, in north-central Cuba**, (Imlay, 1942; Shopov, 1975 and in Kantchev et al., 1978)	**East-central Mexico ,** Huayacocotla remnant of Pessagno et al. (1999), (Mazatepec-Puebla, Poza Rica, and Veracruz-Cantú-Chapa, 1967, 1969, 1976, 1979, 1984, 1989, 1990; Imlay, 1980; Adatte et al., 1996b; Villaseñor and Olóriz, 2001)
Tithonian	*Butticeras butti*, *Butticeras antilleanum*, *Durangites* cf. *acanthicus* , ?*Dickersonia sabanillensis* *Durangites vulgaris*, ?*Haploceras* cf. *veracruzanum*, *Himalayites (Corongoceras)* spp., *H. (Corongoceras) cordobai*, *H. (Micracanthoceras)* spp., *Paralytohoplites carribeanus*, *Protacanthodiscus* sp., ?*Protacanthodiscus* sp., *Protancyloceras catalinense*, *Protancyloceras hondense* *Protancyloceras* sp., *Pseudolissoceras* sp., *Salinites gallardoi*, *Salinites grossicostatum*, *Salinites* sp., *Subdichotomoceras* sp., *Vinalesites rosariensis*, *Windhauseniceras internispinosum*.	*Aulacosphinctoides* sp., *Butticeras* spp., *Durangites* aff. *humboldti*, *Durangites vulgaris*, *Corongoceras filicostatum* (= *Galeanites filicostatum*)[1], *Dickersonia ramonensis*, *Hildoglochiceras* sp. [2], *Himalayites* sp., *Mazapilites symonensis* (?), *Paralytohoplites carribeanus*, *Phylloceras pinarense*, ? *Protacanthodiscus* sp., *Protancyloceras catalinense*, *Protancyloceras hondense*, *Pseudolissoceras* cf. *zitteli*, *Simoceras* sp. cf. *S. volanense*, *Spiticeras (Spiticeras)* sp., *Subdichotomoceras* sp., *Substeueroceras* spp.[3], *Substreblites* sp., *Uhligites* sp., *Vinalesites rosariensis*, *Virgatosimoceras* sp., *Virgatosphinctes* sp, *Windhauseniceras internispinosum*.	*Acevedites* spp., *Aulacosphinctoides pervinquieri*, *Butticeras* cf. *butti*, *Dickersonia* cf. *D. sabanillensis*, *Durangites* sp., *Grayiceras ?* sp., *Haploceras* gr. *complanatum*, *Kossmatia* sp., *Mazapilites tobosensis*, *Mazapilites* sp., *Mazatepites* spp., *Pseudolissoceras zitteli*, *Simoceras* sp., *Simocosmoceras* sp., *Suarites bituberculatum*, *Subdichotomoceras* sp., *Taramelliceras (Metahaploceras)* sp., *Virgatosphinctes mexicanus*, *Volanoceras chignahuapense*, *Salinites* sp.
Berriasian	*Butticeras butti* (?), *B. antilleanum* (?), ?*Bochianites* sp., *Leptoceras* sp., ?*Neolissoceras* sp., *Protancyloceras catalinense*, *P. hondense*, *Salinites* sp., ?*Protancyloceras* sp. A.	*Malbosiceras malbosi*, *Neolissoceras* sp., *Spiticeras* (*Kilianiceras*) sp.	*Durangites* sp., *Groebericeras* aff. *bifrons*, *H. (Salinites)* cf. *alamense*, *Parodontoceras* spp., *Pomeliceras* sp., *Proniceras* sp., *Protancyloceras* spp., *Salinites* sp., *Spiticeras* spp., *Spiticeras (Negreliceras)* sp., *Substeueroceras* spp., "*Subthurmannia*" *mazatepense*, ?*Tirnovella* sp., *Vinalesites* sp.

[1]*After Cantú-Chapa (1998a);* [2]Hildoglochiceras *sp.* = Salinites *sp.(?);* [3]*The ammonites assigned to* Substeueroceras *spp. are not figured in any paper nor unpublished report; the specimens of ammonites collected in the Camajuaní belt were lost (Kantchev et al., 1978). Therefore, any evaluation of the taxonomic position of the ammonites assigned to* Substeureoceras *spp. is not possible.*

(II) *Protancyloceras hondense-Vinalesites rosariensis,* occasionally with *Bochianites* sp. (Houša, 1974), *Salinites,* and *Butticeras* (Myczyński, 1989); and (III) *Leptoceras* spp. (Myczyński, 1977). Assemblages (I) and (II) are early Berriasian in age and (III) is late Berriasian. In the Sierra de los Organos succession, the late Berriasian limestones of the Tumbadero Member (Figure 21A) contain rare juvenile specimens assigned to ?*Protancyloceras* sp. (Figure 18A).

As reported above, scarce Berriasian ammonites of the Placetas belt in the Sierra de Camaján are represented by two assemblages: (I) *Protancyloceras* *catalinense, P. hondense, Salinites* sp., *Butticeras butti*(?), *Butticeras antilleanum*(?), ?*Neolissoceras* sp. and *Bochianites* sp. of early Berriasian age, and (II) ?*Protancyloceras* sp. and *Leptoceras* sp. (Iturralde-Vinent et al., 1981) of late Berriasian age. We conclude that the general character of the Berriasian ammonite assemblages is similar in the Placetas and the Guaniguanico successions. Thus far, *Substeueroceras* and *Parodontoceras* have not been found in these Cuban stratigraphic successions.

4) Late Berriasian to Aptian siliciclastic turbidites are widespread in the Northern Rosario belt of the Guaniguanico Terrane (Polier Formation, Figure 21A), although the main influx of clastic material occurred in the Valanginian-Barremian to early Aptian. The measurements of paleocurrent direction point to transport of the terrigenic material from an eroded area located to the north or northwest of the Polier Formation depocenter (Pszczółkowski, 1978; Pszczółkowski and Albear, 1979). According to Cobiella Reguera et al. (1997), the siliciturbidites of the Northern Rosario belt in western Cuba were derived from a continental block built of granitoids and metamorphic and sedimentary rocks, with contribution from carbonate banks. Pszczółkowski (1978, 1982) recognized a similar composition of the emerged source area, located to the northwest of the sedimentary basin. In some sections of the Veloz Formation that are exposed in the western part of the Placetas belt, turbidite sandstones as much as 0.2-m thick occur as interbeds in the pelagic limestones (Pszczółkowski, 1982). The similar age and petrographic composition of these siliciturbidites indicate a common source for the clastic material and suggest a fanlike mode of sediment transport (Pszczółkowski, 1999). Influx of the terrigenous material ceased in the Aptian.

5) Aptian-Cenomanian radiolarian cherts and shales of the Santa Teresa Formation are similar in the compared tectonostratigraphic belts (Pardo, 1975; Pszczółkowski, 1978, 1982, 1994a). The age of the lower part of the Santa Teresa Formation, however, may be older (late Valanginian to Hauterivian-Barremian) in the Southern Rosario belt (Figure 21A) than in other belts of western and north-central Cuba. In addition, the pelagic limestones and cherts of the Carmita Formation (Cenomanian-Turonian) are comparable in the Placetas (Figure 2) and Guaniguanico (Figure 21A) belts.

In summary, the Cretaceous deposits of the Placetas belt are similar to those of the Northern Rosario belt in the Guaniguanico Terrane, while the Jurassic–earliest Cretaceous strata of these belts are different in their lithology and facies development. Nevertheless, some important Late Jurassic and Berriasian faunal components do occur in both compared Cuban tectonostratigraphic units. Moreover, the ammonites of the Placetas belt are closely related to assemblages described from the Camajuaní belt (Table 4). These observations require that all paleotectonic interpretations of the Placetas, Camajuaní, and Guaniguanico successions should be considered as bio- and paleogeographically coupled during the Tithonian and the entire Cretaceous. In particular, these stratigraphic successions could not be separated widely by any large continental block or wide oceanic basin. In the following chapters, this significant conclusion will be applied to test the previously proposed paleotectonic interpretations involving the Placetas belt in north-central Cuba and/or the Guaniguanico Terrane of western Cuba.

The Proterozoic Marbles and Jurassic Granites: A Southern Mexican Basement of the Jurassic-Cretaceous Succession in the Placetas Belt?

Renne et al. (1989) expressed the idea that the Caribbean Plate transported from the southwest fragments of an extensive Grenville-age belt, namely Late Proterozoic marbles from the Socorro area. According to Sedlock et al. (1993), Precambrian rocks of Grenville age in Mexico and central Cuba were derived from and are allochthonous with respect to the North American Grenville Province. Sedlock et al. (1993) also speculated that the Chortis Terrane and central Cuba (=Placetas succession) were parts of the North American continental arc that were detached and displaced later on, between the Middle Jurassic decline and the middle Cretaceous (Figure 22B, C). About 115–90 Ma, central Cuba appeared in the El Tambor basin, just north of the Chortis block and southeast of the Maya Terrane (Figure 22C; see also Sedlock et al., 1993, Figure 38).

Regarding the reconstruction proposed by Sedlock et al. (1993), the following aspects seem to be significant:

1) The 172.4 Ma age of the granite from Socorro (Renne et al., 1989) implies that this pluton was intruded during early Middle Jurassic time, then uplifted and eroded mainly before onset of the Constancia Formation (Oxfordian?-late Berriasian) deposition. Nevertheless, the erosion of the (Socorro?) granite and/or its arkosic cover continued, locally at least, during the Late Jurassic and Berriasian.

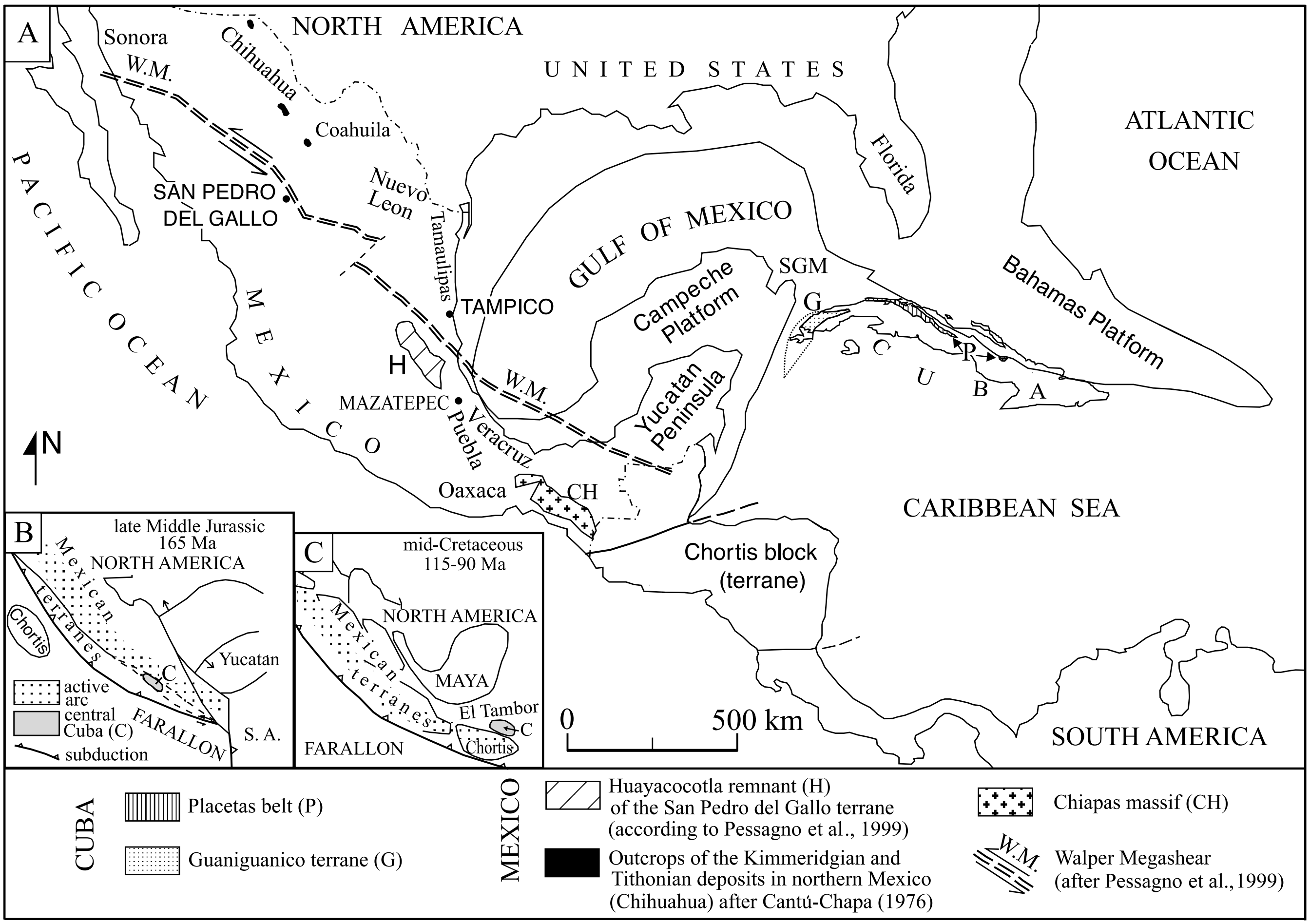

Figure 22. **(A) Map of the Gulf of Mexico and Caribbean area showing location of selected tectonic structures and outcrops in Mexico and Cuba (compiled from various sources; SGM = southeastern Gulf of Mexico). (B) and (C) Simplified paleogeographic reconstructions showing position of central Cuba according to Sedlock et al. (1993): S. A. = South America; El Tambor = El Tambor basin.**

2) Pebbles of volcanic rocks occurring in the arkosic conglomerates (Figure 5) and sandstones, overlying in places the granitic rocks in the Socorro area (pre-Constancia clastics?), could be derived from a pre-Late Jurassic magmatic arc, providing that these clastic rocks are indeed of Middle Jurassic age (Figure 2); their age still is not firmly established.
3) In contrast, clasts of volcanic rocks are scarce or rare in the Constancia Formation sandstones and conglomerates, which are rich in detritic components derived from granitoid and metamorphic rocks. Evidently, the Placetas succession was not supplied with volcanic detritus from an older or coeval (active) volcanic arc during the Late Jurassic–earliest Cretaceous.
4) The latest Jurassic to middle Cretaceous position of central Cuba, as proposed by Sedlock et al. (1993), does not contradict, in principle, the conclusion concerning proximity of the Placetas and Guaniguanico tectonostratigraphic units. By those times, the Guaniguanico successions were located along the eastern (Iturralde-Vinent, 1994, 1996; Pszczółkowski, 1987, 1999) or southeastern margin of the Yucatán block (Hutson et al., 1998). However, during the Tithonian, the distance between the Placetas succession (if located in southern Mexico) and the Camajuaní succession (situated to the south of the Bahamas Platform) could be about 1500–1700 km. In this case, the Tithonian and Berriasian ammonites of the Placetas belt should be similar to the coeval Mexican assemblages, but not to those of the Camajuaní belt in Cuba (Table 4). Actually, the ammonite assemblages of the Placetas belt and of east-central Mexico differ in their endemic taxa

and/or their frequency. For example, *Butticeras,* the characteristic genus in the Cuban assemblages, has been reported thus far (as *Parodontoceras* cf. *butti*) from only one well drilled in Puebla, Mexico (Imlay, 1980). In addition, only one specimen of the Mexican species *Corongoceras cordobai* Verma and Westermann, 1973 was found in the Placetas belt of Cuba (Figure 18C). On the other hand, *Suarites*, *Acevedites, Mazatepites,* and *Kossmatia* (characteristic genera of the Mexican assemblages) are unknown from the Tithonian sections of the Placetas belt (Table 4).

5) The suspected proximity of the Placetas belt and the Chortis block at the end of the Jurassic to middle Cretaceous (Figure 22C; Sedlock et al., 1993, Figure 38) is controversial. The Jurassic–Early Cretaceous successions of the Chortis block (Honduras Group, cf. Donnelly et al., 1990; Gordon, 1992, 1993; Scott and Finch, 1999) and of the Placetas belt seem to be different. A source for the turbiditic sandstones of the Veloz Formation during the Early Cretaceous was located to the northwest of the (western) Placetas belt (Pszczółkowski, 1987, 1999). Published interpretations of the Chortis Terrane position between the Valanginian and Cenomanian are rather divergent (for example, Pindell and Barrett, 1990; Gordon, 1993; Dickinson and Lawton, 2001).

Some of the above-discussed topics do not confirm the scenario proposed by Sedlock et al. (1993); points 3–5, especially, are unfavorable for the Placetas succession position in southern Mexico during the Late Jurassic and Early Cretaceous. However, points 1 and 2 do not contradict the Middle Jurassic location of the Placetas succession in southern Mexico, although the Late Jurassic–Early Cretaceous paleotectonic situation southwest of Yucatan could be even more complex (Tardy et al., 1992; Dickinson and Lawton, 2001).

Western Cuba (and the Placetas Belt): A Displaced Fragment of the San Pedro del Gallo Terrane?

According to Pessagno et al. (1999), Jurassic and Early Cretaceous successions in western Cuba, i.e., Sierra del Rosario and Sierra de los Organos in the Pinar del Río Province (Figure 1B), show lithostratigraphic, paleobathymetric, and paleolatitudinal signatures that are nearly identical to those of San Pedro del Gallo Terrane remnants in central Mexico. According to these authors, the Cuban remnants of the San Pedro del Gallo Terrane were carried from a paleolatitudinal position ~30°N to eastern Yucatán by the Walper Megashear (Figure 22A).

Preliminary paleomagnetic data from the Jurassic San Cayetano (western Cuba) and Collantes (Escambray Terrane, Figure 1A, B) Formations suggest a paleolatitude of about 12° N (Pérez Lazo et al., 1995), and seem to confirm earlier geological interpretations concerning the original location of these Cuban rocks southwest of their present position (Pérez Lazo et al., 1995). However, a moderate number of studied samples and the problem of postfolding magnetization revealed in some formations of the Guaniguanico Terrane (Bazhenov et al., 1996) may suggest that the paleomagnetic studies of deformed Cuban passive-margin successions are in their early stage. Thus, geological and paleontological data still are significant for comparison of Cuban successions with Mexican terranes.

The sections of the Sierra del Rosario and Sierra de los Organos in the Cordillera de Guaniguanico, as presented by Pessagno et al. (1999, Figures 9 and 11), do not agree with some data summarized in Figures 16 and 17 (Pessagno et al., 1999, Figures 9 and 11) and published in various papers (Wierzbowski, 1976; Kutek et al., 1976; Myczyński and Pszczółkowski, 1976; Pszczółkowski, 1978, 1994a, 1999; Iturralde-Vinent, 1994, 1996; Myczyński et al., 1998). For example, the significant hiatus shown between the San Cayetano and Jagua Formations in Figures 9 and 11 of Pessagno et al. (1999) does not exist. In our opinion, the San Cayetano Formation is not composed of "continental red beds" in the Sierra del Rosario. The age and facies development of the deltaic to deep-water San Cayetano Formation of western Cuba (cf. Meyerhoff and Hatten, 1974; Haczewski, 1976) and the Cahuasas Formation in Mexico (red beds, according to Carrillo Martínez, 1960; Carrillo Bravo, 1965; Cantú-Chapa, 1971; Imlay, 1980 and Pessagno et al., 1999) differ. Fresh samples of the San Cayetano Formation deposits are always black in deeply incised rivers and drilled wells. The evaporitic Huehuetepec Formation and the calcarenitic Tepexic Formation (Cantú-Chapa, 1971, 1994), or their equivalents, are unknown from western Cuba. The Oxfordian El Sábalo Formation (Figure 21A), composed of basalts, diabases, and microsparitic limestone interbeds (Pszczółkowski, 1994a), has no stratigraphic and

[4] Cantú-Chapa (1992a) mentions "dispersed layers of igneous rocks" in the Late Jurassic units of his Huasteca Series.

lithologic equivalent in the Huayacocotla remnant of Pessagno et al. (1999)[4].

Only part of the Cuban Jagua Formation (Figure 21A), e.g., the Zacarías and Jagua Vieja members of late-middle and late Oxfordian age (cf. Wierzbowski, 1976, and Myczyński et al., 1998), seems to resemble the Santiago Formation in Mexico (middle Callovian–late Oxfordian). Some characteristic Oxfordian ammonite taxa occurring in the Jagua and Francisco Formations of western Cuba (Judoley and Furrazola-Bermúdez, 1968; Wierzbowski, 1976; Myczyński, 1976) were not reported from the Santiago Formation of east-central Mexico (Cantú-Chapa, 1971; Imlay, 1980). In general, the absence of ammonites belonging to the late Oxfordian *Bifurcatus* Zone in Mexico and southern USA (Myczyński et al., 1998) seems to be characteristic in the circum-Gulf of Mexico sections, but not in the Caribbean ones.

Inferring from the concise description of the San Andrés calcarenites of the Taman Formation given by Carrillo Martínez (1960) and general remarks in some other papers, this unit from east-central Mexico and the San Vicente Member of the Guasasa Formation in western Cuba (Figure 21A) may be different lithostratigraphic units. According to Cantú-Chapa (1971, 1992a, 1993b, 1994), the San Andrés Member is of late Oxfordian to late Tithonian age in wells drilled on the coast of the Gulf of Mexico, and it sometimes overlies unconformably red beds of presumably Jurassic age or even metamorphic and intrusive rocks. This member is considered to be a transgressive unit that locally extends upward, even to the top of the Tithonian (Cantú-Chapa, 1992a).

A sudden deepening of the sedimentary basin from an inner neritic to an upper abyssal zone at the Oxfordian-Kimmeridgian boundary, as reported from the Huayacocotla remnant (Pessagno et al., 1999), did not occur in western Cuba. The Kimmeridgian shallow-marine limestones drilled in the northwestern part of the Placetas belt in Cuba (Alvarez Castro et al., 1998; Rodríguez-Viera et al., 1998) may be a remote facies equivalent to coeval, thick, shallow-water carbonates of the Sierra de los Organos succession in western Cuba, but not to the post-Oxfordian limestones and shales in east-central Mexico described as deep-water deposits (cf. Pessagno et al., 1999).

It seems that *Aulacomyella* is a characteristic bivalve genus for the upper Taman Formation in its type area (Cantú-Chapa, 1984; Longoria, 1988) and the Lower Tithonian sections in east-central Mexico (Cantú-Chapa, 1971), southern Mexico (Cantú-Chapa, 1993a), north-central Mexico (De la Mora et al., 2000), and northeastern Mexico (Michalzik and Schumann, 1994); that is, on both sides of the Walper Megashear of Pessagno et al. (1999). These bivalves, however, were not reported from Cuba (cf. Myczyński, 1999a).

The Tithonian-Berriasian sections existing in the states of Puebla and Veracruz of Mexico (Cantú-Chapa, 1967, 1971; Adatte et al., 1996b) are composed of deposits clearly dissimilar to those occurring in the coeval intervals of the Cuban Artemisa and Veloz Formations. In general, the ammonite assemblages from Mazatepec (Mexico) and Cuba are different, although some rare ammonites belonging to few Tethyan taxa are common for both areas (Villaseñor and Olóriz, 2001); these authors (Villaseñor and Olóriz, 2001) also mentioned Tithonian ammonites of Mexican-Caribbean affinity, oysters, and buchiids[5]. The upper part of the Taman Formation (*sensu* Pessagno et al., 1999) contains late Tithonian *Durangites, Kossmatia,* and *Salinites grossicostatum* (Pessagno et al., 1999, Figure 15). The Berriasian ammonites that are common for the compared areas of Mexico and Cuba belong to the following taxa: *Protancyloceras hondense, P. catalinense,* and *Salinites*. Adatte et al. (1996b) published interesting information on the presence of *Vinalesites* sp. in the middle Berriasian strata (at the boundary of the B and C calpionellid zones) of the Tehepican II section in Puebla, Mexico; unfortunately, this ammonite was not illustrated in their paper. The same taxon (*Vinalesites* sp.) was reported, but also not figured, from the San Pedro del Gallo section (middle Berriasian strata of their La Casita Formation) located about 1000 km to the northwest of the section situated in the state of Puebla (Figure 22A). As confirmed above, *Vinalesites rosariensis* (Imlay) occurs in the strata of Tithonian and early Berriasian age in western Cuba. Other Berriasian taxa known from east-central Mexico (Table 4) were not found in Cuba or have been reported, thus far, only from the Tithonian.

Distribution of *Saccocoma*, *Chitinoidella,* and calpionellids in the Tithonian and Berriasian deposits of Mexico (Adatte et al., 1994), does not favor the paleolatitudinal position ~30°N of western Cuba. *Saccocoma* and *Chitinoidella* are absent in the sections located in northeastern Mexico (states of Tamaulipas, Nuevo León, and Coahuila, Figure 22A), and only isolated levels with these microfossils were found in east-central Mexico (Adatte et al., 1994,

[5] Earlier, Lecolle de Cantú (1967) reported on *Inoceramus bassei* sp. nov., also from Mazatepec; this bivalve is similar to *Anopaea stoliczkai* Holdhaus, 1913 (Lecolle de Cantú, 1967).

1996b). In the former area, rare calpionellids occur in the *Calpionella* Zone (Adatte et al., 1994), but a major change, with the first massive occurrence of calpionellid-rich microfacies, took place in the upper part of the early Berriasian calpionellid zone B (Adatte et al., 1996a). The absence of *Saccocoma*, *Chitinoidella,* and calpionellids of the *Crassicollaria* Zone in northastern Mexico was interpreted to be a result of paleogeographical/paleoclimatological factors (Adatte et al., 1992, 1994, 1996b). A major change in the upper part of calpionellid zone B, accompanied by the appearance of Tethyan ammonites, was recorded in northeastern and east-central Mexico and was linked with drowning of the Florida Straits block (Adatte et al., 1996a, b).

In western Cuba, a relative increase in calpionellid frequency and/or preservation occurred in the late Berriasian *Calpionellopsis* Standard Zone. This phenomenon, however, is not spectacular and might correspond to the maximal spread of calpionellids in the *Calpionellopsis* Standard Zone (Remane, 1998). This weakly marked "event" approximately correlates with eventual submergence of the Placetas clastic depocenters, as well as the beginning of the Yucatán block flooding (Marton and Buffler, 1999). The Tithonian–early Berriasian microfossil assemblages of western Cuba (Furrazola-Bermúdez, 1965; Furrazola-Bermúdez and Kreisel, 1973; Pop, 1976, 1986; Pszczółkowski, 1978; Myczyński and Pszczółkowski, 1990, 1994) may be even more abundant than those from east-central (and southern?) Mexico (cf. Remane, 1998). Therefore, the alleged Tithonian paleolatitude of western Cuba (~30°N) that is to the northwest of northeastern Mexico seems improbable.

Our skepticism also is supported by Upper Jurassic ammonites reported from Chihuahua (Figure 22A) in northern Mexico (Imlay, 1943; Cantú-Chapa, 1976). The early Kimmeridgian transgression was a prominent event in this area, and the general aspect of reported Tithonian ammonite assemblage of *Virgatosphinctes, Kossmatia* spp., *Subplanites fresnoensis* Imlay, and *Suarites* spp. (according to Cantú-Chapa, 1976, 1998b) differs from coeval assemblages known from Cuba. Therefore, there is no evidence that the Cuban successions and the Chihuahua sections were close to one another during the Kimmeridgian and Tithonian.

In fact, the transitional character of Cuban Late Jurassic faunal assemblages is conspicuous. The western Cuban Oxfordian deposits contain ammonites of Mediterranean, Andean, and Caribbean origin (see Chong et al., 1984; Myczyński and Meléndez, 1987, 1990; Meléndez et al., 1988; Myczyński, 1994a, and papers cited therein). The ichthyosaur, plesiosaur, crocodile, and turtle remains from the western Cuban Oxfordian deposits are of particular interest, as they seem to confirm the importance of the early Caribbean seaway (De la Fuente and Iturralde-Vinent, 2001; Gasparini and Iturralde-Vinent, 2001). The early Tithonian ammonite assemblages of western Cuba include Mediterranean, Mexican, and endemic taxa. For example, the assemblage of Sierra de los Organos (western Cuba) is characterized by the presence of *Protancyloceras* (P. *gracile* type, see Myczyński, 1989), a taxon very common in the Mediterranean region and unknown from coeval Mexican horizons. In the late Tithonian and earliest Berriasian assemblages of western Cuba, the endemic taxa (*Protancyloceras*, *Butticeras, Vinalesites,* etc.) and Mexican-Cuban taxa (mostly *Salinites*) are the main components, whereas the Mediterranean influence is less marked. However, lack of Mexican genera— *Mazatepites, Suarites and Acevedites— is a significant feature of the late Tithonian assemblage in western Cuba.*

Late Tithonian and/or Berriasian ammonites are scarce in western California and southwestern Oregon in the U.S.A.; they are accompanied by numerous bivalves of the genus *Buchia* (Imlay and Jones, 1970; Imlay, 1980). Only a few ammonite genera (*Kossmatia, Proniceras,* and ?*Bochianites*) are common for western Cuba and the Oregon–western California areas. The ammonites assigned to *Kossmatia* and *Proniceras* are common in the late Tithonian sections of the San Pedro del Gallo area (Contreras Montero et al., 1988). However, these taxa are scarce in western Cuba. Buchiids also are scarce in western Cuban sections. The Tithonian bivalves from western Cuba were identified mainly as inoceramids (Myczyński, 1999a). The significance of the occurrence of the genera *Inoceramus*, *Retroceramus*, *Anopaea* (interpreted by Crame and Kelly, 1995, as amphitropical bivalves), and *Buchia* is not yet fully explained. According to Coleman et al. (1995) and Myczyński (1999a), distribution of these bivalves could be controlled, rather, by oceanic currents and upwelling than by tectonic transport from higher (northern) paleolatitudes. Furthermore, in the Sierra del Rosario, the inoceramids and buchiids appeared during the early Tithonian. In the Sierra de los Organos, these bivalves essentially occur in the upper Tithonian strata, and their "acme" clearly coincides with the presence of some ammonites of Pacific origin (for example, *Aulacosphinctoides, Pseudoinvoluticeras, Phanerostephanus*, *Aulacosphinctes*, *Micracanthoceras,* and *Corongoceras;*

see Myczyński, 1989). These Late Tithonian deposits contain also abundant fish (*Teleostei*) remains, which are very common in the Jurassic of Argentina, Chile, Mexico, the United States, Canada, and Japan (see Cione, 1992). However, it seems that the ammonite genus *Salinites* is limited to the Gulf of Mexico, eastern Mexico, the southern United States, and proto-Caribbean basin margins (Cantú-Chapa, 1989; Myczyński, 1999b). This genus is unknown from the San Pedro del Gallo and Sierra de Catorce sections in Mexico (Contreras Montero et al., 1988; Cantú-Chapa, 1989; Verma and Westermann, 1973; Olóriz et al., 1999), as well as along the Pacific coast of North and South America (Myczyński, 1999b). Therefore, presence of *Salinites* in the Cuban sections is not in agreement with a late Tithonian position of the Guaniguanico Terrane close to the Pacific coast.

The effects of the Jurassic transgressions were different in east-central Mexico and Cuba. In the former area, the Middle Jurassic transgressive phases (Cantú-Chapa, 1992a, 1998b) were marked by sedimentation of various deposits, sometimes biostratigraphically well-documented by ammonites. Unfortunately, contrary to the Mexican sections, there is no satisfactory biostratigraphic control of the San Cayetano Formation rocks in the Sierra de los Organos (western Cuba), as a result of lack of ammonites. The early Kimmeridgian transgression, well known in Mexico (Cantú-Chapa, 1971, 1992b, 1998b; Pessagno et al., 1999), was not marked in the Guaniguanico successions of western Cuba, where it is roughly coeval with the shallowing phase (Pszczółkowski, 1999). The transgressive phase, which occurred at about the time of the Kimmeridgian/Tithonian boundary, and well known from western Cuba (Pszczółkowski, 1978, 1999), was not recognized in east-central Mexico (Pessagno et al., 1999). The early Tithonian drowning of the shallow-water carbonates of the Guaniguanico successions could be related to the onset of rapid postrift thermal subsidence of the Yucatán block (Marton and Buffler, 1993).

In our opinion, the above-discussed dissimilarities in lithostratigraphy, facies development, paleobathymetry, and faunal assemblages between the Huayacocotla remnant and the Guaniguanico and Placetas successions are not in agreement with the conclusion of Pessagno et al. (1999, p. 123) that the Jurassic and Early Cretaceous successions in western Cuba are "nearly identical to those of San Pedro del Gallo Terrane remnants in central Mexico."

The radiometric dating of mica grains from the San Cayetano Formation supports the idea that this unit has formed along the southeastern margin of the Yucatán Peninsula (Hutson et al., 1998). However, Pessagno et al. (1999) assume that the southern part of the Yucatán block was moved together with the Guaniguanico Terrane (or "fragment") of western Cuba during its tectonic transport along the Walper Megashear (Figure 22A). As concluded above, the Placetas, Camajuaní, and Guaniguanico successions should be considered as bio- and paleogeographically coupled during the Tithonian and the entire Cretaceous. The alleged tectonic transport along the Walper Megashear should involve, in fact, a large 800–1000-km-long terrane composed of the Guaniguanico and Placetas/Camajuaní (?) successions. However, the Early Cretaceous evolution of the above-mentioned successions was remarkably quiet, with deposition of pelagic limestones and turbiditic sandstones in a deep-water depocenter of the paleogeographically coupled Guaniguanico-Placetas Formations (Pszczółkowski, 1999). In particular, there is no sign of any syn-sedimentary tectonic disturbance connected with the supposed movement of the Cuban "remnant" between the Yucatán block (northern part) and the Chiapas massif (Figure 22A) during the Aptian-Albian. And last but not least, the Camajuaní succession probably was linked with platform carbonates of the Remedios zone by a transitional stratigraphic succession (see below); therefore, its removal from the southern margin of the Bahamas Platform into the area adjacent to the Pacific coast during the Tithonian-Berriasian is difficult to accept.

The Placetas Succession as Southern, Deep-water Fringe of the Bahamas Platform and/or the Proto-Caribbean Basin Section

The interpretation linking the origin of the Placetas succession with the southern slope of the Bahamas, or with the North American Mesozoic paleomargin in central Cuba (Cobiella Reguera, 2000), and/or the proto-Caribbean basin (Rosencrantz, 1995; Iturralde-Vinent, 1996, 1997, 1998) is currently accepted by many authors (e.g., Alvarez Castro et al., 1998; Kerr et al., 1999; Stanek, 2000; Stanek et al., 2000). Nevertheless, some problems still deserve a closer study, or even reconsideration of recently proposed paleogeographic schemes (Alvarez Castro et al., 1998).

The Camajuaní succession (Figure 2) is thought to represent slope deposits of the "toe of the slope" of the Bahamas Platform (Cobiella Reguera, 2000) and, in part, the succession of the Proto-Caribbean basin

(Iturralde-Vinent, 1998). In some oil wells drilled in the Cuban Northern Oil Province— in particular, in the offshore areas north of Matanzas Province — the Camajuaní stratigraphic succession was found below the Placetas tectonic units (Echevarría-Rodriguez et al., 1991; Tavares Noa et al., 1994). This type of tectonic structure also is known from seismic data (Domínguez Garcés et al., 1998) and was described from outcrops (Pszczółkowski, 1983). According to Sánchez et al. (1994), a section intermediate between the Remedios and Camajuaní belts (named Colorados) was drilled in the Hicacos Peninsula (Figure 1C). This 3000-m-thick section consists of (1) Tithonian-Aptian allodapic limestones, (2) Albian-Cenomanian deposits (debris-flow), and (3) Turonian-Maastrichtian calciturbidites (Sánchez et al., 1994). The Colorados stratigraphic succession is probably less deformed than that of the Camajuaní and may be a transitional section linking the platform carbonates (Remedios) with the deep-water Camajuaní succession (Sánchez et al., 1994; Alvarez Castro et al., 1998). The Camajuaní succession may be interpreted as the northern component of remnants of the Caribbean-Tethys oceanic basin (or Proto-Caribbean basin) preserved as thrust slices between the Remedios belt and the Zaza volcanic arc (Rosencrantz, 1995). In this interpretation (Rosencrantz, 1995), the Placetas belt represents the southern, highly deformed remnants of the Proto-Caribbean floor succession.

The occurrence of basement slivers between the Placetas tectonic units is a problem that still is not fully explained. According to Renne et al. (1989), the Grenvillian rocks occurring in the Placetas belt do not fit the Gondwanian rocks of Florida and the southeastern Gulf of Mexico (DSDP sites 537 and 538A, see Dallmeyer, 1989). These authors concluded that the Caribbean Plate transported from the southwest fragments of an extensive Grenville-age belt that spanned the Americas during the Late Proterozoic. Rowley and Pindell (1989) located the "Rio Cana Complex" (mainly the Socorro–La Teja marbles) between Florida and the Precambrian basement of northern South America. However, these authors (Rowley and Pindell, 1989) concluded that the absence of Pan-African and/or Alleghenian overprinting in the marbles probably reflects a large separation of the "Rio Cana Complex" from these orogenic effects. Iturralde-Vinent (1994, 1996, 1997) considered the Late Proterozoic marbles and metasiliciclastics, as well as the Middle Jurassic granite, to be the basement of the Florida Straits block (cf. Pindell, 1985). Recently, Iturralde-Vinent (1998) interpreted the Placetas and the Northern Rosario successions as deposits of the Proto-Caribbean basin and combined this conjecture with the Central American–Mexican origin of the above-mentioned Late Proterozoic rocks (Renne et al., 1989). However, the pre-Late Cretaceous position of the Placetas succession has not been indicated in schematic paleogeographic maps (Iturralde-Vinent, 1998, Figure 20). In addition, the Encrucijada Formation (Fonseca and Zelepugin, 1981; Pszczółkowski, 1987) of the Felicidades succession in the Bahía Honda area (Figure 1B) may be interpreted as part of the Proto-Caribbean basin floor (Iturralde-Vinent, 1997; Kerr et al., 1999).

Nevertheless, a substantial part of the Placetas succession probably was deposited on the (thinned) continental crust, as evidenced by the Constancia Formation siliciclastics. Stratigraphic data do not confirm interpretation of the entire Placetas succession as the remnants of the oceanic basin section. Only the southernmost Tithonian deposits of the Placetas succession, exposed in the Sierra de Camaján (Iturralde-Vinent and Marí Morales, 1988), may represent the Proto-Caribbean basin section deposited on the oceanic floor. This may be explained by the Cretaceous (pre-late Campanian) subduction of a southwestern portion of the Proto-Caribbean (=Placetas?–Northern Rosario?–Felicidades) oceanic floor or— alternatively— by its Albian-Maastrichtian tectonic shortening, as proposed by Kerr et al. (1999).

The Late Jurassic siliciclastic deposits of the Placetas belt have no equivalent in the Camajuaní belt in north-central Cuba (Figure 2) and, contrary to the opinion expressed by Alvarez Castro et al. (1998), are not similar to those of the San Cayetano Formation in the Guaniguanico successions of western Cuba (Figure 21A). The clastic material for the Constancia and San Cayetano Formations was shed from diverse sources, as evidenced by their different composition and grain roundness, and judging from the paleocurrent directions for the latter unit (Haczewski, 1976; see also Pszczółkowski, 1999). Evidently, both formations accumulated in dissimilar paleogeographic conditions, on various parts of the continental margin of North America (the Bahamas Platform and the Yucatán Block, respectively) and during different time intervals (Oxfordian?–late Berriasian and Lower Jurassic?–middle Oxfordian, respectively). The Tithonian-Berriasian clastics of the Constancia Formation were deposited in paleotectonic conditions roughly similar to those described from the southeastern Gulf of Mexico (Figure 22A) by Marton and Buffler (1994). During the middle to late

Berriasian, these clastic deposits continued to accumulate, probably in areas elevated in respect to the adjacent grabens or half-grabens influenced by carbonate sedimentation since the Kimmeridgian (Alvarez Castro et al., 1998) or since (late) early Tithonian (Sierra de Camaján, Iturralde-Vinent and Marí Morales, 1988). Apparently, the Tithonian–early Berriasian paleogeography was more complex than that schematically shown by Alvarez Castro et al. (1998, Figure 3). The clastic deposition finally was replaced by pelagic sedimentation of radiolarian-nannoplankton biomicrites in the late Berriasian, even in the most elevated areas of the Placetas belt. The general picture of the Late Jurassic–Berriasian sedimentation in the Placetas succession seems to be comparable to that recognized in the southeastern Gulf of Mexico (Marton and Buffler, 1999).

In the Sierra Morena area (Figure 1C), the Early Cretaceous limestones of the Placetas belt are strongly folded and cut by numerous calcite veins in a zone close to the tectonic contact with the Camajuaní belt (Pszczółkowski, 1983). The Placetas/Camajuaní tectonic contact in this area shows features of an important overthrust separating two different tectonostratigraphic units (cf. Hatten et al., 1988). To the southeast of Sierra Morena and Rancho Veloz, this tectonic contact is characterized in many places by the occurrence of tectonic breccia (or mélange) composed of serpentinite with numerous blocks of various, mainly igneous, rocks (San Felipe zone and overthrust of Knipper and Cabrera, 1974). Considering the above-described tectonic situation, paleogeographic and paleotectonic reconstructions implying a pretectonic depositional continuity of the Camajuaní and Placetas belts are not sufficiently supported by conclusive structural evidence. Nevertheless, on the basis of stratigraphic data, original proximity or even continuity of both belts is probable. A similar composition of the Tithonian ammonite assemblages is evident (Table 4). In addition, a general correlation of the lithostratigraphic units is consistent with a gradual change of facies from north to south, especially in the Valanginian-Cenomanian deposits (Figure 2). Finally, lack of Turonian-Campanian (or Late Turonian? to Campanian) deposits in the Placetas and Camajuaní belts (Pardo, 1975; Knipper and Cabrera, 1974; Pszczółkowski, 1986) also confirms that both successions originated in the same basin, in similar paleogeographic and paleotectonic conditions. Comparable conditions also existed during deposition of the Sierra del Rosario successions (Pszczółkowski, 1978, 1999) and in the southeastern Gulf of Mexico, especially during the Late Cretaceous (Schlager et al., 1984).

SUMMARY AND CONCLUSIONS

The original, nontectonic contacts between the Late Proterozoic basement rocks and Middle Jurassic granite and the Placetas succession are not documented from outcrops or from wells drilled in north-central Cuba. Nevertheless, the shallow-marine arkosic deposits covering these Late Proterozoic and Middle Jurassic rocks are similar to the arkosic sandstones and conglomerates of the Constancia Formation (Oxfordian?–late Berriasian) in the Placetas succession, in that they contain abundant granitoid-derived clastic material. The arkosic clastics with scarce bioclasts of bivalves, echinoderms, algae, and bryozoans may be older (late Middle Jurassic? or earliest Late Jurassic?) than the shallow-marine, arkosic sandstones and conglomerates of the Constancia Formation. Our data concerning the Early Cretaceous (Berriasian) age of the uppermost part of the Constancia Formation in some outcrops of north-central Cuba do not confirm the exclusively Late Jurassic (and even pre-Tithonian) age of all deposits of the Constancia Formation in the entire Placetas belt of north-central Cuba.

Our study adds some new data to the stratigraphy of the Tithonian-Berriasian limestones in the Sierra de Camaján in Camagüey Province. The occurrence in the upper Tithonian–lower Berriasian of some ammonite taxa typical for the Guaniguanico sections in western Cuba is confirmed herein. We report *Butticeras butti* (Imlay, 1942) and *B. antilleanum* (Imlay, 1942) from the lower Tithonian of the Sierra de Camaján section. Our observations strongly suggest that *Butticeras butti* (Imlay, 1942), *Protancyloceras hondense* (Imlay, 1942), and *P. catalinense* (Imlay, 1942) disappeared in the Berriasian. We also recognize the presence of two Berriasian ammonite assemblages in the Sierra de Camaján section. We confirm an earlier suggestion that the limestone of the uppermost part of the El Americano Member of the Guasasa Formation of western Cuba is early Berriasian in age, at least in some sections. We conclude that the general character of the Berriasian ammonite assemblages is similar in the Placetas and Guaniguanico successions in Cuba.

The Cretaceous deposits of the Placetas belt are similar to those of the Northern Rosario belt of the Guaniguanico Terrane in western Cuba, while the Jurassic–earliest Cretaceous strata are different in their lithology and facies development. Nevertheless, some important Late Jurassic and Berriasian faunal components do occur in both compared Cuban belts. Moreover, the Tithonian ammonites of the Placetas succession are closely related to the assemblage reported from the Camajuaní belt in north-central Cuba. These observations require that the Placetas, Camajuaní, and the Guaniguanico successions should be considered in all paleotectonic interpretations as bio- and paleogeographically coupled during the Tithonian and the entire Early Cretaceous. Therefore, these stratigraphic successions could not be widely separated by any large continental block and/or oceanic basin.

Our observations on the Tithonian-Berriasian ammonite assemblages of north-central Cuba and Mexico are not consistent with the reconstruction of the Placetas belt paleotectonic evolution proposed by previous authors. The Early Cretaceous and Cenomanian deep-water formations of the Placetas belt do not contain deposits suggesting a presence of a nearby continental block to the south (Chortis Terrane). However, data concerning the basement rocks and the arkosic cover do not contradict the Middle Jurassic location of the Placetas succession in southern Mexico. In our opinion, dissimilarities in lithostratigraphy, facies development, paleobathymetry, and faunal assemblages existing between the Huayacocotla remnant in Mexico and the Guaniguanico and Placetas successions of Cuba do not confirm the opinions of other authors that the Jurassic and Early Cretaceous successions in western Cuba are nearly identical to those of San Pedro del Gallo Terrane remnants in central Mexico. Moreover, the composition of Late Jurassic ammonite assemblages in western Cuba is not in agreement with the paleolatitudinal position of the Guaniguanico Terrane at $\sim$30°N and close to the Pacific coast.

The occurrence of basement slivers between the Placetas tectonic units is a problem that still is not fully explained. Only the southernmost Tithonian deposits of the Placetas belt (Sierra de Camaján) may represent the basinal sections deposited on the Proto-Caribbean oceanic floor. The Late Jurassic to earliest Cretaceous siliciclastic deposits of the Placetas belt (Constancia Formation) are not similar, nor coeval, to those of the San Cayetano Formation in the Guaniguanico successions of western Cuba. On the basis of stratigraphic data, the paleogeographic proximity of the Placetas and Camajuaní successions is probable. The Cretaceous deposits of both successions originated in the same basin, and in similar paleogeographic and paleotectonic conditions.

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ADDED IN THE PROOF

Recently, Alva-Valdivia et al. (2001) have published results of their paleo- and rock-magnetic (pilot) study carried out on the Jurassic-Cretaceous rocks from the Guaniguanico Cordillera. Alva-Valdivia *et al.* (2001) concluded that no major latitudinal displacements have affected the Guaniguanico Cordillera since the Jurassic, in contrast to some previously proposed tectonic models. This result is in accordance with the earlier paper by Pérez Lazo et al. (1995) and with our conclusions of the present contribution.

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