The Conflicting Paleontologic versus Stratigraphic Record of the Formation of the Caribbean Seaway

Manuel A. Iturralde-Vinent
Museo Nacional de Historia Natural, Havana, Cuba

ABSTRACT

This paper presents a set of paleogeographic maps that illustrate the formation and evolution of the Caribbean from latest Triassic to latest Jurassic. Stratigraphic data and plate-tectonic models indicate that the Caribbean first evolved as a system of latest Triassic–Middle Jurassic rift valleys in west-central Pangea. Probably since the Bajocian, but certainly since the Oxfordian, it became a marine seaway connecting western Tethys with the eastern Pacific. In contrast, abundant paleontological data strongly suggest that the seaway across west-central Pangea opened during the Early Jurassic (Hettangian-Pliensbachian), which data conflict with the stratigraphic data. This contradiction between paleontology (biogeographic interpretations) and stratigraphy (paleogeographic interpretation) reveals our insufficient knowledge about the Mesozoic geology of west-central Pangea.

This paper is a contribution to IUGS/UNESCO IGCP Project 433.

INTRODUCTION

It is well known that paleoceanography, global paleoclimate, and the evolution of biota are strongly related to paleogeographic changes on the earth’s surface and are linked to the evolution of marine seaways (Berggren and Hollister, 1974; Frakes et al., 1992; Parrish, 1992). The Caribbean is an important example of this because, since its very early formation, it has played an important role in controlling the patterns of ocean water circulation, moderating global climate, and controlling biotic exchange between surrounding terrestrial and marine ecosystems. Following this line of thought, the paleontologic record (and its biogeographic interpretations) must be congruent with the stratigraphic record, which supports the paleogeographic reconstruction of the area. But a conflict undoubtedly exists about how paleontologic and stratigraphic data record the early history of the Caribbean.

Abundant paleontologic data from the eastern Pacific and the western Tethyan continental margins of Pangea suggest that very early in the Jurassic (Hettangian or Pliensbachian), there was a marine connection across west-central Pangea (Gasparini, 1978, 1992; Smith, 1983; Riccardi, 1991; Gasparini and Fernández 1996; Damborenea, 2000; Aberhan, 2001). This connection first yielded a limited exchange of shallow-marine taxa (Smith, 1983; Damborenea, 2000;
Aberhan, 2001), but with time, the waterway widened (Pindell, 1994; Lawver et al., 1999), allowing an increasing exchange of marine animals including both open- and shallow-marine taxa that were limited during the Bathonian-Oxfordian and extensive since the Oxfordian (Westermann, 1981, 1992; Hillebrandt, 1981; Hillebrandt et al., 1992; Imlay, 1984; Sandoval and Westermann, 1986; Bartok et al., 1985; Riccardi, 1991; Gasparini, 1992; Gasparini and Fernández, 1996; Iturralde-Vinent and Norell, 1996; Damborenea, 2000).

The purpose of this paper is to present the conflicting paleontologic and stratigraphic data in order to encourage more debate and further research on this important stage of the evolution of our planet when west-central Pangea opened into the Gulf of Mexico and the Caribbean sea.

**Paleogeography**

The paleogeographical maps presented in this paper include two sets of maps for the latest Triassic to Late Jurassic time interval (Figures 1 and 2). The global maps (Figure 1) are less accurate and mainly portray the general outline of land and sea, taking as a base the plate-tectonic reconstruction of Lawver et al. (1999) with minor modifications regarding the original position of the Andean and Piñon-Dagua + Siquisique terranes (Aleman and Ramos, 2000). The paleocoastlines are redrawn from Gradstein et al. (1990), Salvador (1991), Riccardi (1991), Smith et al. (1994), Pindell and Tabbut (1995), and Randazzo and Jones (1997). These maps are needed to understand how paleogeography and biogeography are connected. The Caribbean maps (Figure 2) are more accurate, and were elaborated using recent plate-tectonic models (Iturralde-Vinent, 1998; Lawver et al., 1999; Marton and Buffler, 1999) with minor modifications regarding the original position of the Andean and Piñon-Dagua + Siquisique terranes (Aleman and Ramos, 2000). These maps depict land and several shallow-marine facies as well as deep-marine facies (>100 m water depth). The database for the construction of these maps is summarized in Table 1 and in Figures 3 and 4. These more detailed maps display the local changes that took place in the Gulf of Mexico–Caribbean realm as the pathway controlling the marine connection between the Tethys/Atlantic and Pacific realms.

The following paragraphs discuss the latest Triassic to latest Jurassic paleogeographic transformation of Pangea into the Gulf of Mexico and the Caribbean and present the conflicting stratigraphic and paleontologic evidence. Table 1 and Figures 3 and 4 present

![Figure 1](image-url) - (a) Early Jurassic, (b) Middle Jurassic, and (c) Upper Jurassic global paleogeographic maps. See text for explanation and sources of data. The white arrows in (c) suggest routes of marine dispersion.
the basic tectonic framework and stratigraphic data used to construct the paleogeographic maps.

**Latest Triassic–Early Jurassic**

Near the end of the Triassic, the earth’s pre-Mesozoic continental crust was amalgamated as a single supercontinent named Pangea, a huge sialic mass that was assembled during the late Paleozoic. The Tethys Ocean extended eastward to Panthalassa, the precursor of the Pacific Ocean, which surrounded Pangea (Figure 1). The breakup of Pangea began under the conditions depicted in Figure 1.
During latest Triassic–Early Jurassic (Figure 1), Pangea was a major barrier to the dispersion of marine biotas, as it blocked any equatorial dispersion. Many nonpelagic marine organisms probably were forced to surround Pangea in order to migrate close to the continental shelf. One can hypothesize that the land biotas at that time were able to disperse across Pangea, but the occurrence of a developing network of rift basins and valleys (similar to present-day East African rift valleys) probably would have created some restrictions and preferred pathways for the migration of terrestrial animals (Figure 1). A major branch of these rift basins extended along the present-day continental margin of North America into the present-day Gulf of Mexico, and along the suture where the Atlantic Ocean and Caribbean Sea ultimately opened (Figures 1, 2A, and 2B; Bullard et al., 1965; Klitgord et al., 1988; Gradstein et al., 1990; Milani and Thomaz Filho, 2000). These rift basins should not be thought of as the Caribbean basin or the Gulf of Mexico per se, but as precursors located in west-central Pangea (Iturralde-Vinent and MacPhee, 1999).

Intracontinental extension persisted into the Early Jurassic, widening the rift systems and subsequently developing large aquatic basins, mostly lakes and rivers (Klitgord et al., 1988; Bartok, 1993; Pindell, 1994; Milani and Thomaz Filho, 2000). The strata filling these rift basins typically are continental red beds, including paleosols, alluvial, and lacustrine sedimentary rocks, which generally predate the deposition of evaporitic strata in the areas that later evolved into marine basins (Evans, 1978; Salvador, 1987; Poag and Valentine, 1988; Gradstein et al., 1990). Evidence of this process can be seen from the north to central Atlantic, where marine inundation and salt deposition progressively extended southward beginning in the Hettangian (Poag and Valentine, 1988; Gradstein et al., 1990). On the African side of the Atlantic between the Demarara plateau and Cape Verde islands, the older marine rocks are of Early Cretaceous age (Hayes et al., 1972; Jones et al., 1995).

**Figure 2.** Latest Triassic through Late Jurassic west-central Pangea paleogeographic maps. Sources of data for the maps are summarized in Table 1 and Figure 4. See text for explanation. The arrows in B, C, and D suggest possible routes of marine dispersion.
Table 1. Land and marine indicators for selected geological units of the Caribbean region and its surroundings, latest Triassic to latest Jurassic (220–135 Ma). Current location of terranes is shown in Figure 3.

<table>
<thead>
<tr>
<th>Geological unit or terrane</th>
<th>Current location of the geological unit (Figure 3)</th>
<th>Land indicators: (1) hiatuses (2) red beds, alluvia, paleosols, fossils (3) near-shore conglomerates and/or lagoonal sediments</th>
<th>Marine indicators: rocks of (1) shallow and (2) deep-water environments, and (3) marine evaporites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bahamas Platform–North Cuba</td>
<td>Bahamas–North Cuba deformed belt</td>
<td>(2) pre-Oxfordian: Meyerhoff and Hatten, 1974, Jacobs, 1977</td>
<td>(1) Kimmeridgian(?) and younger: Meyerhoff and Hatten, 1974; Jacobs, 1977 (3) undefined Middle Jurassic: Meyerhoff and Hatten, 1974</td>
</tr>
<tr>
<td>Chortis Block</td>
<td>Central America</td>
<td>(2) pre-Cretaceous: Maurrasse, 1990</td>
<td>No record of Jurassic marine sediments</td>
</tr>
<tr>
<td>Andean terranes</td>
<td>Northern South America</td>
<td>(1 and 2) pre-Cretaceous boundary (1 and 2) pre-Cretaceous: Maze, 1984; Parraud et al., 1995</td>
<td>(1) Late Jurassic: González de Juana et al., 1980; Macsotay and Peraza, 1997 (1 and 2) Major transgression in Lower Cretaceous: González de Juana et al. 1980; Parraud et al., 1995</td>
</tr>
<tr>
<td>Peñon-Dagua terrane</td>
<td>Northern South America</td>
<td>(2) Bathonian-Bajocian: Bartok et al., 1985</td>
<td></td>
</tr>
</tbody>
</table>
In the Florida-Bahamas block, which in effect played the role of “gatekeeper” between the Atlantic and Caribbean, reflection data have revealed the existence of two rift basins. One rift basin is epicontinental and is filled with terrigenous clastic sediments (Sheridan et al., 1988, Figure 7). The only well in the Bahamas intersecting this section was the Great Isaac #1, which penetrated red beds of Jurassic (probably Callovian) age above crystalline basement rocks (Meyerhoff and Hatten, 1974; Jacobs, 1977). Equivalent rock sections also have been intersected by deep exploratory wells and/or outcrop locally in northwestern Cuba. Meyerhoff and Hatten (1974) reported 336 m of pre-Tithonian–Neocomian quartz siltstone, quartz wackes, and lithic arkose overlying basement rocks. Also, according to unpublished deep exploratory well logs, Callovian-Oxfordian terrestrial sediments are found underlying Kimmeridgian-Tithonian marine limestones (Carlos Sosa, personal communication, 2001). Another rift basin is located in the transition between continental and oceanic crust, and its sedimentary fill contains Late Jurassic and younger limestones, dolomites, and evaporites (Sheridan et al., 1988, Figure 7). This interpretation of the age of the rocks is confirmed not only by the Great Isaac #1 well (Jacobs, 1977), but also by stratigraphic sections of the southern margin of the Bahamas platform that crop out in north-central Cuba, where rift-fill consists of Callovian through Early Cretaceous dolomite, limestone, anhydrite, gypsum, and halite of the Punta Alegre, Cayo Coco, and Perros Formations (Meyerhoff and Hatten, 1968, 1974; Iturralde-Vinent, 1994, 1998). These evaporites usually have been correlated with the Werner Anhydrite and Louann Salt of the United States Gulf of Mexico Province (Meyerhoff and Hatten, 1968, 1974), but this interpretation is challenged here because the North Cuba–Bahamian evaporites were deposited in a different basin, separated from the Gulf of Mexico by a basement high (the Florida-Yucatan ridge; Figure 2B and C). As such, I propose that the North Cuba–Bahamian evaporites (Punta Alegre and Cayo Coco Formations of Meyerhoff and Hatten [1968, 1974]) are an extension of the evaporite systems developed during the opening of the Atlantic Ocean, from north to south as they outcrop in the fold belt (Gradstein et al., 1990).

In the circum-Caribbean area, no marine rocks of latest Triassic age are known (Figures 3 and 4), and Lower Jurassic rocks are not properly identified. It is possible that portions of the oldest continental-margin sections of the proto-Caribbean may have been dragged into and “lost” in subduction zones, but this does not seem to apply to the Florida-Bahamas block (Sheridan et al., 1988), the North Cuba–Bahamian area (Meyerhoff and Hatten, 1968, 1974), or the Cuban Southwestern terranes (Pinos, Escambray, and Guaniguanico terranes; Figure 3) because they contain Jurassic and even pre-Mesozoic basement rocks (Figure 4; Somin and Millán, 1981; Renne et al., 1989; Pszczolkowski, 1999; Iturralde-Vinent, 1998).

The only known marine rocks of Lower Jurassic Pliensbachian age in the circum-Caribbean region are radiolarites and red ribbon cherts associated with basalts in the Dominican Republic (Montgomery et al., 1994). However, these rocks are part of the allochthonous Pacific crust of the Caribbean plate (Montgomery et al., 1994; Pindell, 1994); therefore, they have no bearing on the age of the Caribbean Sea as a geographical entity.

In the Mexican terranes (in western Laurasia), there occur some marine intercalations of Sinemurian–early Pliensbachian age as part of the Triassic–Early Jurassic continental deposits of the Huayacocotla Formation (Figures 3 and 4; López-Ramos, 1975); but these marine incursions seem to be related to transgressions from the Pacific Ocean (Salvador, 1987, 1991). Therefore, the presence of marine environments, even of short duration, in the latest Triassic and Lower Jurassic sections of the south-central Atlantic, Florida-Bahamas, Gulf of Mexico, northern South America, or the Caribbean proper cannot be demonstrated conclusively (Table 1; Figures 3 and 4).

The stratigraphic data previously discussed (Table 1; Figures 3 and 4) conflict with the biogeographic-based thesis that states that since the Hettangian or Pliensbachian, the “Hispanic Corridor” was active as a marine route for the exchange between west Tethyan and eastern Pacific biotas (Gasparini, 1978; Smith, 1983). But the paleontologic data overwhelmingly support this point of view (Hillebrandt, 1981; Westermann, 1981; Imlay, 1984; Bartok et al., 1985; Sandoval and Westermann, 1986; Hillebrandt et al., 1992; Westermann, 1992; Gasparini, 1992; Gasparini and Fernández, 1996; Boomer and Ballent, 1996; Damborenea, 2000; Aberhan, 2001). According to some recent biogeographic interpretations for the Lower Jurassic, some brief marine incursions should have taken place during sea-level highs, which acted as a filter to allow only shallow-marine organisms to disperse (Damborenea, 2000; Aberhan, 2001). The sea-level curve does not adequately support this point of view because its relative position since the latest Triassic and up to the Middle Jurassic (Bajocian) was generally low,
although there were several highstands during this time (Figure 4). If marine biota dispersed across west-central Pangea, this phenomenon probably took place along the latest Triassic–middle Jurassic rift basin systems (Figures 1 and 2), but marine sediments of this age have not been reported in these rift basins. Only lagoonal deposits and localized evaporites are found in the stratigraphic record, which yield fish remains, including elasmobranchia of probable marine origin (van Houten, 1962; Smith and Robison, 1988; Poag and Valentine, 1988). Thus, if some brief marine incursions occurred, as paleontologic data so strongly suggest, they are not yet documented properly, suggesting that more research has to be done in the Newark Supergroup and equivalent units.

Another possibility, which contradicts the biogeographic thesis, is that marine biota did not disperse across west-central Pangea during the latest Triassic–Middle Jurassic, but rather around the supercontinent, following the southern seaway, the Viking corridor, or both (Figure 1). Such dispersion may have been possible when polar waters were not so cold, as a result of the warm climatic period that expanded from the Permian until the Middle Jurassic (Frakes et al., 1992). But such a possibility, if accepted, implies that we are not going to credit the paleontologic record.

**Middle Jurassic**

By the Middle Jurassic, the physical separation between Laurasia and Gondwana was in progress. The west-central Pangean intracontinental rift system was under development, with contemporaneous deposition of siliciclastic sediments (Poag and Valentine, 1988; Gradstein et al., 1990; Bartok, 1993; Pindell, 1994; Milani and Thomaz Filho, 2000).

Several authors have documented the Jurassic paleogeographic evolution of the Gulf of Mexico, but there is not clear agreement among them. According to Stephan et al. (1989) and Smith et al. (1994), the Gulf was a marine tongue of the Pacific that occupied the Mexican terranes and the western Gulf of Mexico beginning in the Sinemurian, and expanded during the Bathonian as far as the Florida peninsula. This interpretation contradicts seismic and stratigraphic data that suggest that the Gulf of Mexico was not a marine basin until the late Bathonian-Callovian.
By the Callovian, the Gulf had developed an oceanic crust, and hypersaline marine environments covered an extensive area (Figures 1 and 2; Winker and Buffler, 1988; Salvador, 1987, 1991; Sawyer et al., 1991). The Maya Block, the southeastern Gulf of Mexico, and Florida were part of a long peninsular projection of the North American continent (a “landspace” as per Iturralde-Vinent and MacPhee, 1999). This Florida-Yucatan emergent ridge (Figures 1 and 2) must have had a land biota whose fossil remains have not been discovered yet, probably because of limited outcropping (see maps by López-Ramos, 1975; Viniegra-O, 1981).

Regarding the Caribbean area, Middle Jurassic marine rocks of Bajocian-Bathonian age have been reported from the Guaniguanico terrane of western Cuba and in the Siquisique basalts of Venezuela (Piñon-Dagua + Siquisique terranes) (Table 1; Figure 2B and Figure 3). As the Piñon-Dagua terrane (and the Siquisique basalts) are interpreted as allochthonous Mesozoic oceanic crust accreted to the Andean terranes (Pindell, 1994; Aleman and Ramos, 2000), they are not an unequivocal indication of marine environments in the Caribbean; neither do their occurrences suggest that a marine corridor was under development (Bartok et al., 1985; Bartok, 1993). In the

Guaniguanico terrane (Figures 3 and 4), the Lower (?)–Middle and Early–Late Jurassic San Cayetano Formation is interpreted generally as having been deposited in a continental coastal plain, with terrestrial, alluvial, lagoonal, and shallow-marine components (Haczewski, 1976). However, Lower Jurassic strata have never been identified positively in the San Cayetano Formation (Pszczolkowski, 1978, 1999), and strata of Middle Jurassic age are represented by (1) Lower (?)–Middle Jurassic black shales that contain the coastal plant *Piazopteris branneri* (Areces-Malléa, 1990), (2) Bajocian (?) marine sandstones containing mollusks that include *Trigonia (Vaughonia)* (Krömmelbein, 1956; Pszczolkowski, 1978), and (3) Bajocian-Bathonian marine shales with palynomorphs and dinoflagellates (Dueñas Jiménez and Linares, 2001). Jurassic siliciclastic and carbonate rocks exhibiting various degrees of metamorphism also have been reported from the Pinos and Escambray terranes in Cuba (Figures 3 and 4), but the few marine fossils found in these pre-Oxfordian sections are so poorly preserved that precise age assignment remains problematic (Millán, 1981; Millán and Myczynski, 1979; Somin and Millán, 1981; Millán and Somin, 1987). Another problem related to the Cuban Southwestern terranes (Figure 3; Pinos, Guaniguanico and Escambray) is their original position, which has been debated at length in recent years. Presently, several independent data sources indicate that these terranes formed in the Caribbean borderland of the Maya Block (Figure 2B) (for discussions see Iturralde-Vinent, 1994, 1996, 1998; Bralower and Iturralde-Vinent, 1997; Hudson et al., 1999; Pszczolkowski, 1999; Pessagno et al., 1999).

In Florida and the Bahamas, the occurrence of Middle Jurassic marine sedimentary rocks has not yet been documented (Table 1, Figure 4); here again, the possible existence of a marine pathway across the Florida-Bahamas area is problematic because of the lack of stratigraphic control. Middle Jurassic marine rocks are not reported from northern South America (because the Bathonian-Bajocian Siquisique basalts probably are allochthonous [Aleman and Ramos, 2000] nor from the area of the Demarara plateau–Cape Verde islands (Hayes et al., 1972; Jones et al., 1995).

As such, the hypothesis that the Caribbean was a fully functional marine seaway and the circum-Tropical Marine Current was active during Middle Jurassic time (Gradstein et al., 1990) remains equivocal. The occurrence of marine sediments of this age in Siquisique (Píñon-Dagua + Siquisique terranes) and in the Cuban Southwestern terranes can be explained as a reaction to the crustal extension between South America and the Maya Block (Lawver et al., 1999) that produced a marine basin that opened into the Pacific. But the possibility that this early Caribbean intercontinental embayment was in communication with the Atlantic since the Bajocian is only a working hypothesis (Figures 1 and 2) that requires further confirmation in the stratigraphic record of the Demarara-Bahamas region. Thus, the conflict between stratigraphic and paleontologic data persists.

**Upper Jurassic**

By the Late Jurassic, the gap between North America and Gondwana had widened, and true marine basins with oceanic crust were developing both in the Caribbean and the Gulf of Mexico (Table 1; Figures 1 and 2D). The approximate westward direction of the circum-Tropical Marine Current, probably since the Bathonian but certainly since the Oxfordian, is suggested by physical paleoceanographic evidence (Parrish, 1992) and the suspected migratory routes of marine invertebrates (Berggren and Hollister, 1974; Imlay, 1984; Damboorena, 2000).

The evolution of the Gulf of Mexico in the Late Jurassic generally is well understood (Salvador, 1991; Bueffler and Thomas, 1994; Pindell, 1994; Marton and Bueffler, 1999). Until the Callovian, it was a restricted saline basin, but in the Oxfordian, a generalized marine transgression from the Pacific covered wide areas with shallow-marine carbonate and shale deposits of the Smackover and Zuloaga formations (Table 1; Salvador, 1991). Sometime during the Kimmeridgian-Tithonian, the southwestern Gulf was drowned by shallow-marine environments and the Gulf of Mexico became a new marine corridor (added to the Caribbean seaway) connecting the Atlantic with the Pacific Ocean (Salvador, 1991; Marton and Bueffler, 1999). This event probably produced a subdivision of the circum-Tropical Marine Current into two branches (see Berggren and Hollister, 1974). In the scope of this paper, it is not possible to explore the biogeographic and paleoclimatic implications of the opening of the Gulf of Mexico as a new seaway into the Caribbean, but important changes in the composition of the marine biota must have taken place, especially in North America. Another implication of this event was the possible isolation of the terrestrial biota that eventually inhabited the Florida-Yucatan emerged rise (Figures 1 and 2). On the other hand, the widening gap between North America and Gondwana limited the possibility of direct, overland dispersal between the land biotas of these continental
areas. Probably since the Bajociam but surely since the Oxfordian, such a possibility ceased to exist (Figures 1 and 2; Iturralde-Vinent and MacPhee, 1999).

In the Caribbean, Upper Jurassic marine rocks are well developed (Figures 1, 2, and 4). In the Cuban Southwestern terranes, the Callovian through Oxfordian was a time of transition between siliciclastic and carbonate marine deposition (Pszczolkowski, 1978; 1999; Millán and Myczynski, 1979; Somin and Millán, 1981). The middle-late Oxfordian Jagua Formation of western Cuba contains a rich fossil assemblage that includes terrestrial, coastal, and open-marine species (Pszczolkowski, 1978; Iturralde-Vinent and Norell, 1996; Fernández and Iturralde-Vinent, 2000; De la Fuente and Iturralde-Vinent, 2001; Gasparini and Iturralde-Vinent, 2001). This implies that the Caribbean Seaway by this time had opened widely enough to allow exchange of pelagic marine biota between the western Tethys and eastern Pacific realms (Figures 1 and 2; Iturralde-Vinent and Norell, 1996; Fernández and Iturralde-Vinent, 2000).

By the end of the Jurassic, deeper marine environments had developed in the Caribbean continental margin off Yucatan (Pszczolkowski, 1978, 1999; Sánchez-Barreda, 1990; Schaffhauser et al., 2000), and the Caribbean probably reached its maximum width early in the Cretaceous (Pindell, 1994).

In the North Cuba–Bahamas area, Late Jurassic marine rocks have been intersected by exploratory wells and outcrops in northern Cuba (Meyerhoff and Hatten, 1968, 1974; Sheridan et al., 1988). These sections represent a passive-margin domain, with restricted shallow-carbonate and evaporitic facies in the Bahamas and continental-slope deposits that developed to the south beginning in the Kimmeridgian–Tithonian (Meyerhoff and Hatten, 1968, 1974; Iturralde-Vinent, 1994; 1998). During the Late Jurassic, the Atlantic-Caribbean deep-water circulation may have taken place eastward of the Bahamas, because the Straits of Florida did not open as a deep-marine channel until the Early Cretaceous (Figures 2C and D; Buffler and Hurst, 1995).

In the northern continental margin of South America, the paleogeographic scenario was different. The latest Triassic and Jurassic strata are represented generally by continental red beds with paleosols, alluvial, and lake deposits that yield fossils of terrestrial plants as well as fresh-water invertebrates (Figures 3 and 4; González de Juana et al., 1980; Maze, 1984). Some Late Jurassic marine beds occur in this overall continental section, represented mostly by intercalations of limestone, clastic-carbonate rocks, and shales, which are more common and thicker toward the continental edge. These marine rocks contain Late Jurassic fish (Lepidotus and elasmobranchia), middle–late Jurassic corals (Aplophyllia), and Kimmeridgian through Lower Cretaceous ammonites (González de Juana et al., 1980, Maze, 1984; Algar and Erikson, 1995; Macsotay and Peraza, 1997).

Therefore, no conflict exists for the Late Jurassic between the stratigraphic and paleontologic data, because the paleogeographic evolution of the Caribbean–Gulf of Mexico area is congruent with the biogeographic interpretations.

ACKNOWLEDGMENTS

The author wishes to thank Zulma Gasparini (Natural History Museum, La Plata) for sharing relevant paleontological data, and for extensive discussions about the historical biogeography of the Jurassic marine reptiles. Lisa Gahagan and Larry Lawver (University of Texas at Austin) provided access to the program PLATES for the plate-tectonic reconstruction of the Caribbean. Support for field and laboratory research for this paper in the Greater Antilles and Argentina was provided by grants 6001/97, 6009/97, and 6984/1 from the National Geographic Society, the American Museum of Natural History, the Institute for Geophysics and the Institute for Latin American Studies of the University of Texas at Austin, the Museo Nacional de Historia Natural de Cuba, and other sources.

REFERENCES CITED


Viniegra-O, F., 1981, Great carbonate bank of Yucatan,